

Appendix 6

Groundwater Quality Investigation

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Groundwater Quality Investigation

**No.3 Shaft, Perilya North Mine,
Broken Hill**

for Perilya Broken Hill Limited
December 2011

J1262.9R-rev0

CMJA

C. M. Jewell & Associates Pty Ltd

CMJA

Groundwater Quality Investigation - No.3 Shaft, Perilya North Mine, Broken Hill

December 201111

J1262.9R-rev0

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List of Abbreviations

Measures

µg/L	micrograms per litre
km	kilometre
L	litre
m	metre
m ²	square metre
µS/cm	microsiemens per centimetre
mS/cm	millisiemens per centimetre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mm	millimetre

General

AHD	Australian Height Datum
AMG	Australian Map Grid
ANZECC	Australian and New Zealand Environment and Conservation Council
AST	above-ground storage tank
CLM Act	Contaminated Land Management Act
CMJA	C. M. Jewell & Associates Pty Ltd
COPC	contaminants of potential concern
DA	development application
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water
DLWC	Department of Land and Water Conservation
DNAPL	dense non-aqueous-phase liquid
DNR	Department of Natural Resources
DP	deposited plan
DQO	data quality objectives
EPA	Environment Protection Authority
ESA	Environmental Site Assessment
GDE	groundwater dependent ecosystems
HDPE	high-density polyethylene
MNA	monitored natural attenuation
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
PID	photoionisation detector
PQL	practical quantitation limit
ppmv	parts per million volume
PSH	phase-separated hydrocarbons
QA	quality assurance
QC	quality control
RAP	remediation action plan
RL	relative level
RPD	relative percentage difference
SWL	standing water level
TCLP	Toxicity Characteristics Leaching Procedure
THI	target hazard index
TOC	top of casing
TWA	time weighted average
UCL	upper confidence limit
UST	underground storage tank

List of Abbreviations



Analytes – Organic

BaP	benzo(a)pyrene
BTEX	benzene, toluene, ethylbenzene, xylene
OCP	organochlorine pesticides
OPP	organophosphorus pesticides
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
SVOC	semivolatile organic compounds
TPH	total petroleum hydrocarbons
VHC	volatile halogenated compounds
VOC	volatile organic compounds

Analytes – Inorganic

As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Ni	Nickel
Pb	Lead
Zn	zinc

1.0 INTRODUCTION

1.1 Background

The groundwater quality investigation that this report describes, relates to the west cage of the No.3 Shaft (west cage), Perilya North Mine, Broken Hill.

The North mine is situated in high-grade metamorphic rocks of the Early Proterozoic Willyama Supergroup in the Broken Hill Block of western New South Wales.

The Broken Hill orebody is one of the largest known base metal deposits in the world, having produced over 200 million tonnes of high-grade ore over the 126 years of mining. The ore deposit, which consists of six or more distinct lode horizons, is generally strata-bound, with intense structural modification along shears and related folds causing complex ore geometries and upgrading of mineralisation.

The Broken Hill mine is currently being actively mined by Perilya Broken Hill Limited (Perilya), who acquired the mine from Pasminco Limited in 2002. Perilya manages over 1024 square kilometres of prospective terrain, including exploration licences over the historic Little Broken Hill and Pinnacles areas, and mine leases incorporating the Southern Operations, North Mine, and Potosi Line.

Perilya's Broken Hill operation predominantly produces two products, a zinc concentrate and a lead concentrate. Concentrates are a premium coarse-grained product, being of low complexity and containing a grade of about 50% zinc in the zinc concentrate and 70% lead in the lead concentrate.

Perilya is continuously re-appraising known mineral deposits in the area and reviewing all historical data in order to identify new resource targets. As part of these works, Perilya has identified the known mineral resources in the lowermost levels of the North Mine – referred to as the North Mine Deep – and the ore remaining in the Fitzpatrick Lode, as one of the key mine expansion programs that would extend the life of the Broken Hill mine. Previous mineral resource drilling has shown that the remaining ore in the North Mine Deep contains an estimated mineral resource of 3.7 million tonnes at 11.3% zinc, 13.5% lead and 219 g/t silver, making it an attractive proposition.

However, given that it has been over 20 years since deep mining activities were undertaken at the North Mine, Perilya is facing the challenge of dewatering the old working prior to the recommencement of any future operations in the North Mine Deep. This is considered to be a significant task, particularly when assessing the treatment options for the groundwater upon extraction, which Perilya has identified as a key issue in deciding whether the lower levels of the North Mine – including the Fitzpatrick Lode – will become realistic operational target in the future.

In 2006, as part of the pre-planning phase of works, Perilya commissioned C. M. Jewell & Associates Pty Ltd (CMJA) to conduct a preliminary assessment of the quality of the groundwater stored in the old workings, to identify suitable reuse and possible disposal options for the water. The groundwater was highly saline and heavy metal concentrations, in particular – manganese, iron and zinc – were above the relevant criteria for the options considered. Overall, it was concluded that the water in the North Mine would require some sort of treatment (i.e. oxidation, filtration and/or desalination) before most reuse options become feasible.

As five years have passed since CMJA's preliminary assessment, Perilya considered that an additional (up-to-date) groundwater assessment was required. Accordingly, Brain Kilty of Perilya commissioned CMJA on 10 August 2011 to:

- conduct further investigation of the quality of groundwater stored in the North Mine workings, and

- provide Perilya with recommendations regarding reuse or disposal options for the water,

as outlined in CMJA's Proposal for Water Level Measuring and Sampling – Shaft No.3 North Mine, Broken Hill (ref. J1262.8L, dated 20 July 2011).

This report presents the results of that additional assessment.

1.2 Project Objectives

As indicated above, the objectives of the project were to provide Perilya with an overview of quality of the water in the No. 3 Shaft, and to provide Perilya with recommendations regarding reuse or disposal options for the water.

1.3 Scope of Work

The scope of work carried out to achieve the project objectives included the following.

- Camera survey of the No.3 Shaft (West Cage) in order to provide Perilya with video documentation of the condition of the infrastructure within the shaft. Camera surveys were also carried out in order to ensure that the selected profiling run was clear of any blockages or obstructions that could hinder the geophysical logging and groundwater sampling programs.
- Water level measurements (+/- 1.0 metre).
- Geophysical profiling of the water column of the No.3 Shaft – Profiling consisted of two combined fluid resistivity and temperature (including differential temperature) runs between approximately 724 and 1177 metres depth through the floor of the West Cage carriage.
- Assessment of the geophysical profiling results and selection of target intervals for water quality characterisation purposes.
- Collection of three groundwater samples from selected intervals of the accessible water column (i.e. 780 metres, 970 metres and 1160 metres depths RL) using discrete interval groundwater sampling techniques.

Note: An additional geophysical run was conducted while the samples were obtained.

- Submission of samples to a NATA accredited laboratory for analysis for:
 - major anions (chloride, sulphate, carbonate and bicarbonate);
 - major cations (sodium, calcium, magnesium and potassium);
 - heavy metals (arsenic, cadmium, chromium (total, Cr III and Cr VI), copper, lead, manganese, nickel, zinc, iron, mercury, silver);
 - sulphide;
 - total dissolved solids (TDS);
 - total suspended solids (TSS); and
 - oil and grease.
- Interpretation of the analytical results in reference to relevant criteria including the *Australian Drinking Water Guidelines* (ANZECC/ARMCANZ 2011) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000).
- Preparation of this report.

1.4 Report Format

Section 2 of this report provides a brief description of the site, history of the North Mine, and a brief overview of the local geology and hydrogeology.

Section 3 identifies the contaminants of concern and the applicable assessment criteria.

Section 4 presents an overview of the work undertaken during the assessment, including a description of the down-shaft camera and geophysical surveys, groundwater sampling methodology and sample handling procedures. An overview of the scope of works carried out, including a timetable of site activities, is also included in this section.

Section 5 presents the results of the geophysical survey and analytical works carried out by the environmental laboratory.

Section 6 provides an overview of reuse and treatment options for the water within the workings including oxidation, filtration and desalination processes. Given the concentrations evident within the water in the North Mine it is anticipated that the use of several of these options may be required to reduce concentrations to suitable levels for reuse options to be explored.

Section 7 presents the conclusions and recommendations of the investigation.

In addition to the information presented and discussed within the text, factual and supporting data used during the investigation are included in a series of appendices at the end of the report.

A copy of the Borehole Summary Worksheet for registered borehole GW021882 – which is discussed in Section 2 of this report – is presented in Appendix A. Information presented on the log includes the depth of the bore, geological formations encountered during drilling and general information relating to the quality of groundwater in the vicinity of the bore.

Appendix B of this report presents an overview of groundwater quality information for several boreholes drilled in the southern lease areas around Broken Hill. Analytical results provide an insight into the quality of groundwater occurrences in this area and, given that these boreholes were drilled as part of mineral exploration and mineral resource assessments along the Broken Hill Line of Lode, are considered to provide information regarding the quality of groundwater occurrences for similar workings in the area, including the North Mine.

Appendix C presents an extract of a technical review regarding Hydrasleeve™ discrete groundwater sampling bladders. The extract has been taken from a review of groundwater sampling methods and technologies carried out by the United States Army Corps of Engineers which details the use, benefits and limitations of the bladders compared with other groundwater sampling methodologies. The article also provides a description of how the bladders function – particularly given their relatively simplistic design – and their reliability in controlled environments, particularly when dealing with volatile and oxidation-reduction (redox) sensitive analytical suites.

Appendix D of this report includes copies of the chain-of-custody and sample-receipt-advice documentation for the samples submitted for laboratory analysis.

A copy of the certificate of analysis forwarded by the analytical laboratory is provided in Appendix E.

Appendix F provides copies of the quality assurance (QA) and quality control (QC) information, including the details and results of laboratory control samples including surrogate, matrix spikes and method blank samples. A discussion regarding the analytical methods, QA/QC outliers such as

holding time non-compliances, quality control frequencies and sample preservation issues – and internal performance of the laboratory is also provided on the certificates.

Appendix G presents copies of relevant water quality trigger values for a range of water uses in Australia including drinking water, surface water and irrigation water. Trigger values include the Health Guidelines listed in the *Australian Drinking Water Guidelines* (2011), and trigger values set for the protection of 95% of species in fresh water, and short- and long-term trigger values for heavy metals and metalloids in irrigation water listed in Tables 3.4.1 and 4.2.10 respectively as listed in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). These tables have been included in this report in order to provide Perilya with a reference point for future water disposal investigations and also to present the current guideline values that would need to be met if such avenues are explored.

Copies of the logs produced during the geophysical logging of the West Cage shaft are provided with this report. The logs visually display the resistivity and temperature of the water column in the No. 3 Shaft measured during each of the geophysical runs, with differential temperature also shown. The logs were produced by the NSW Office of Water (NOW) on completion of the fieldwork and have been presented in full with this report.

1.5 Limitations and Intellectual Property Matters

This report has been prepared by C. M. Jewell & Associates Pty Limited for the use of the client identified in Section 1.1, for the specific purpose described in that section. The project objectives and scope of work outlined in Sections 1.2 and 1.3 were developed for that purpose, taking into consideration any client requirements and budgetary constraints set out in the proposal referenced in Sections 1.1.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation. An information sheet – ‘Important Information about your Environmental Site Assessment’ – is provided with this report. The report should be read in conjunction with that information sheet.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

This report, the original data contained in the report, and its findings and conclusions remain the intellectual property of C. M. Jewell & Associates Pty Ltd. A licence to use the report for the specific purpose identified in Section 1.1 is granted to the persons identified in that section on the condition of receipt of full payment for the services involved in the preparation of the report.

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2.0 BACKGROUND

2.1 Location

The North Mine is located on the Barrier Highway on the north-eastern outskirts of the township of Broken Hill; its location is shown on Figure 1.

Mining operations at the North Mine have historically been carried out from a vast complex of underground stopes and drives which were accessed by three shafts – namely the No. 1, No. 2 and No. 3 Shafts – and an open-cut pit towards the southern end of the former lease.

2.2 Perilya's Broken Hill Operations

Mining in the Broken Hill area, under Perilya's management, commenced in July 2002. Mining is principally carried out using a longhole open stope method, with variations developed for extraction of the secondary resource located in the previously worked pillars area. Longhole stoping accounts for about 70% of underground production, with pillar extraction and development ore contributing to 30% respectively of the total.

The Broken Hill operation produces two premium coarse-grained products: a zinc concentrate and a lead concentrate, which contain a grade of about 50% zinc and 70% lead, respectively. Both concentrates are railed to Port Pirie in South Australia where, in general, the lead concentrate is smelted and the zinc concentrate is exported.

Between 2002 and 2010, Perilya mined over 15 million tonnes of ore and exported over 800,000 tonnes of zinc and 450,000 tonnes of lead.

Perilya currently owns both the North Mine and South Mine. Production at the North Mine ceased in August 2008, but a pre-feasibility study into the viability of mining the lower levels has commenced in order to ascertain the viability of re-opening the North Mine (upper and deep lodes).

The Southern operation's underground workings are accessed through three shafts and a decline. The shafts include the Main Haulage shaft, the Main Service Shaft and the Southern Cross Shaft. At its current deepest point, the mine reaches about 1200 metres below the surface, and there are more than 90 kilometres of accessible drives.

2.3 History of the North Mine

The North Mine was born in mining lease Block 17, which was pegged out by Julius Nickel and James Anderson on 22 December 1883. In 1885, the lease was acquired for £15,000 by a Melbourne syndicate, which formed the Broken Hill North Silver Co. Limited; however, the company quickly fell on difficult times and a new company was registered to work the lease in 1888. This company also fell on difficult times owing to falling global base metal prices, and eventually went into voluntary liquidation in the mid 1890s. It was later sold for £1750.

Throughout the 1890s turbulent economic times meant that shareholders in the venture did not see a dividend until 1899, and in 1901 operations ceased owing to a downturn in the economic cycle.

In 1904 the increase in global base metals prices saw the mine open again. Later that year the company acquired the Victorian Cross lease – located immediately to the north of Block 17 – which was found to contain a much larger and richer ore deposit than the original lease. In the following decades, the mine purchased numerous other mining leases, including the British (1923), the Junction (1929), Junction North (1931) and Block 14 (1942) leases, all of which proved to be fruitful to varying degrees; with the exception of Junction North, these blocks were transferred to the ailing Broken Hill South Company in 1962, and subsequently to Mineral, Mining and Metallurgy in 1972.

As mining operations moved northwards and away from conventional open-cut mining methods, new access shafts and infrastructure were required to chase the plunging lode. The No. 1 Shaft was excavated in 1905, quickly followed by the No. 2 Shaft in 1928. During the early 1940s it was clear that the lode was plunging further away from No. 2 Shaft, and it was decided that a third shaft was needed further north along the strike in order to chase out the ever-plunging lode. The No. 3 Shaft – which is elliptical in shape compared to its circular predecessors – was completed in 1947, and by 1962 had reached a depth of 1300 metres. Between 1966 and 1972 it was deepened and eventually reached 1580 metres.

In 1975, the Fitzpatrick Lode – consisting of an estimated 2 million tonnes of high-grade lead, silver and zinc ore – was discovered further down-plunge of the No. 3 Shaft. Owing to its depth and its distance from the older workings an internal shaft was constructed at the lower levels of the No. 3 Shaft reaching from the 32 level to the 36 level. In 1989, work began on an extension of the internal shaft to the 40 level, and by this time a new company, Pasminco, had been formed to merge the lead and zinc interests of North Broken Hill Peko Limited and CRA, then the operator of the South Mine.

With the formation of Pasminco, the northern and southern Broken Hill mining activities were managed and operated as one entity. This however was a relatively short-lived venture with operations at the North Mine ceasing in February 1993.

This history of the North Mine between 1993 and 2002 remains unclear, although it is understood that Perilya purchased the North Mine in 2002 when it was still operating. Perilya's operations at the North Mine ceased in August 2008.

The North Mine has produced over 32 million tonnes of ore from its underground workings and nearly 2.5 million tonnes from its open pit operations, and there are plans to extend the life of the mine through the Fitzpatrick Lode (as discussed within this report).

2.4 Geological Setting

The geology of the Broken Hill area has been intensively studied, perhaps more so than that of any other comparably-sized area in Australia. This work has revealed stratigraphy, structure and mineralisation of great complexity. Although a detailed description of these features is clearly beyond the scope of the report, a summary is deemed appropriate in order to provide an understanding of the geochemistry of the water within the North Mine. The following paragraphs have been distilled from a number of sources, including Cooper (1975), Stevens and Stroud (1983), Burton (1994), Barnes (1988) and Stevens et al. (2003).

The metamorphic rocks underlying Broken Hill and the immediately surrounding area form part of the Willyama Supergroup, which is of Proterozoic age. Radiometric dating indicates depositional ages ranging from 1700 to 1640 million years (Ma) for these rocks. Around Broken Hill, and in the ranges to the north and west, the Willyama Supergroup crops out at the surface. In the eastern and southern part of the extended area, and to the east of the Broken Hill block, the Proterozoic rocks are blanketed by sediments of much younger (Cainozoic) age.

The generalised stratigraphic sequence for the Willyama Supergroup is shown on Figure 2. The Supergroup is composed of medium to high-grade metamorphic rocks – originally volcanic, volcanoclastic and sedimentary deposits, now transformed to pelite, psammite, gneiss and migmatite. The rocks have all been deeply buried, and subjected to high temperatures and pressures; kyanite and staurolite mineral assemblages suggest that the rocks were subjected to pressures up to 4 kilobars (kb) – equivalent to a burial depth between 12 and 20 kilometres – and heated to temperatures of about 700 degrees Celsius (°C). The highest-grade rocks, the migmatites, have been completely melted, and the

others have undergone recrystallisation that has radically changed their mineralogy and internal structure, and resulted in the complete elimination of their original pore-space.

Structurally, the rocks in the area are part of the Broken Hill Block, one of the main structural/stratigraphic units of the area. The rocks have been heavily deformed by multiple phases of folding, and are also faulted. Two main groups (Group 1 folds, which have deformed the lithologic layering and generated the regional schistosity, and Group 2 folds, which have deformed the regional schistosity) and two minor groups of folds have been mapped.

The Proterozoic rocks in the Broken Hill area have been intensively mineralised. The Broken Hill main lode, which extends for more than 7 kilometres along a north-east strike, alone contained more than 280 million tonnes (Mt) of lead–zinc–silver mineralisation prior to the commencement of mining; it is also thought that some 80 to 90 Mt of ore rock has also been removed predominantly in solution from the lode during the last 65 million years. There are also many lesser lodes in the area.

The primary ores are massive and disseminated sulphides – principally galena and sphalerite – hosted in garnet–quartz rocks. There was an extensive gossan (oxidised) zone above the sulphide ore. Whilst several theories for ore genesis have been proposed, the currently favoured explanation is that the ores were precipitated onto the sea-floor from brines expelled from the upper mantle. Figure 3 shows the geology and mineralisation of the Broken Hill area in greater detail.

2.5 Overview of Ore Body Geology and Geochemistry

The Broken Hill mine is situated in high-grade metamorphic rocks of the Early Proterozoic Willyama Supergroup in the Broken Hill Block of western New South Wales.

The Broken Hill Lode consists of six or more distinct lode horizons, and is globally significant due to its high metal content – albeit with the significant absence of high gold and/or copper grades. It is generally strata-bound, and exhibits intense structural modification along shears and complex ore geometries, although it is markedly different from other sediment-hosted exhalative deposits owing to the lack of abundant pyrite (FeS₂), pyrrhotite (FeS) barite (BaSO₄) and other sulphates.

The Broken Hill Lode is also significantly different from other lead, silver and zinc deposits in that its mineralogy is typically ‘sulphur poor’. Its mineralogy is dominated by ferroan sphalerite and gahnite, plumbian orthoclase (a lead-enriched feldspar), sulphur-poor antimonides, native metals and rare base metal-bearing silicates and oxides; its high manganese, calcium, halide (especially fluoride and bromide), phosphorus and uranium content are also striking features which make it one of the most diverse mineral deposits in the world.

Mineralisation in the Broken Hill Lode consists of a series of parallel silver-lead rich and zinc-lead rich lenses that have been deformed and structurally complicated resulting in zones of localised sulphide enrichment. Economic mineralisation predominantly consists of galena (lead sulphate) and iron-rich sphalerite (iron zinc sulphide), whilst other common ore minerals include pyrrhotite (an iron sulphide), chalcopyrite (copper iron sulphide), arsenopyrite (iron arsenide sulphide), loellingite (silver chloride) and cerussite (lead carbonate); gangue mineralogy (i.e. the ‘waste’ materials left over after removing the minerals of interest from the ore) includes quartz, feldspar, gahnite, garnet calcite, fluorite and a variety of manganese silicates including spessartine and tephroite.

Economic mineralisation is typically distinguished by the presence of quartz-gahnite, quartz-garnet schists and gneisses, blue quartz and plumbian orthoclase which form common ore-identifying marker units throughout the area. The orebodies are hosted within pelitic-psammitic metasediments, basic gneiss, quartz-spessartine (a quartz and manganese-rich garnet rock commonly referred to as garnet sandstone), quartz-gahnite (a quartz and zinc aluminium oxide rock), and ‘Potosi-type’ gneiss – a

quartz-feldspar, biotite-garnet gneiss that dominates the host lithology at the Potosi open-pit mine just to the north-east of the North Mine. These rocks are termed lode horizon rocks.

Mineralisation primarily occurs in small discontinuous lenses or as weak disseminations in the lode rock. In total there are six known lenses that have undergone multiphase coeval deformation and high-grade metamorphism which has resulted in structurally complicated zones of sulphide enrichment and complex mineral assemblages. In many places, the lode rocks are complexly folded in sympathy with the country rocks, with the ore lenses themselves showing substantial thickening at fold hinges and closures. Due to remobilisation during ductile deformation, tonnage and grade is significantly higher in the hinges of folds and during brittle deformation, particularly where high grade Lead Lode has been transposed into shear zones.

2.6 Overview of Groundwater Quality of the Willyama Supergroup

Borehole summary worksheets held by NOW report water quality in boreholes extracting from the Willyama rocks and regolith as generally 'good', occasionally 'brackish'. The water quality suffices for stock watering.

Samples from Borehole GW021882 (of which a full analytical summary is provided in Table 1) had total dissolved solids content ranging from 3700 to 3900 milligrams per litre (mg/L), with sulphate of about 650 mg/L and chloride of about 1500 mg/L. This bore is located at Farmcote Station, about 10 kilometres south-west of the centre of Broken Hill, and was drilled to a depth of 67.1 metres.

A copy of the Borehole Summary Worksheet is provided in Appendix A.

TABLE 1
Groundwater Chemistry – Bore GW021882
All concentrations in mg/L^a (ppm^b)

Date	pH ^c	Major Cations				Major Anions				TDS ^g	NO ₃ ^h	Fe	SiO ₂ ^k
		Ca	Mg	Na	K	CO ₃ ^d	HCO ₃ ^e	SO ₄ ^f	Cl				
17 Mar 1978	7.8	160	158	920	17	0	384	605	1446	3690	14	2	21
18 Jun 1979	7.2	188	160	954	18	0	409	648	1514	3891	14	2	19
19 Sep 1979	7.6	176	155	963	17	0	391	663	1540	3905	16	3	20

Notes:

- ^a milligrams per litre
- ^b parts per million
- ^c reported in pH units
- ^d carbonate; reported as milligrams per litre of calcium carbonate
- ^e bicarbonate; reported as milligrams per litre of calcium carbonate
- ^f sulphate
- ^g total dissolved solids
- ^h nitrate
- ^k silica

A program of groundwater sampling carried out from exploration boreholes in the southern leases indicated total dissolved solids generally in the range 8000 to 10,000 mg/L, with sulphate typically 1500 to 2800 mg/L and chloride 2500 to 5000 mg/L.

Heavy metal concentrations in groundwater derived from the lode horizons are elevated. The data indicate that cadmium, manganese, lead and zinc, as well as iron, are present at significant concentrations with cadmium concentrations exceeding those considered suitable for stock use.

A summary of the groundwater quality data for the southern leases is presented in Appendix B.

3.0 DISSOLVED COMPONENTS OF INTEREST AND APPLICABLE CRITERIA

3.1 Contaminants of Concern

To assess the water quality, the following suite of analytes were selected:

- major anions (chloride, sulphate, carbonate and bicarbonate)
- major cations (sodium, calcium, magnesium and potassium)
- heavy metals (arsenic, cadmium, chromium (total, Cr III and Cr VI), copper, lead, manganese, nickel, zinc, iron, mercury, silver)
- sulphide
- total dissolved solids (TDS)
- total suspended solids (TSS)
- oil and grease

3.2 Assessment Criteria

In order to provide a human health and environmental context to the measured dissolved-phase concentrations, the analytical results have been assessed against relevant criteria.

For the assessment of potential human health issues relating to the consumption of untreated water from the North Mine, it is considered that the appropriate criteria are those presented within the Health Guidelines listed in the *Australian Drinking Water Guidelines* (2011), jointly prepared by the National Health and Medical Research Council (NHMRC) in collaboration with the Natural Resource Management Ministerial Council (NRMMC). These levels relate specifically to water that is to be used for human consumption, and although they do not represent mandatory standards for the quality of water for human consumption, they do offer a framework for identifying acceptable water quality.

For the assessment of potential environmental impacts arising from the interaction of untreated water from the North Mine with freshwater aquatic ecosystems (such as the Imperial Lake), it is considered that the appropriate criteria are those trigger values set for the protection of 95 per cent of species in fresh water and listed in Table 3.4.1 of ANZECC's *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

Trigger values included in Table 2 are the values applying to slightly-moderately disturbed systems, and have been derived for use in assessing surface waters. In the absence of specific levels for groundwater, the surface-water trigger values have been used.

For the assessment of issues relating to the use of the water for irrigation purposes, it is considered that the appropriate criteria are those values presented in Table 4.2.10 of ANZECC's *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). The values presented in this table represent long-term (up to 100 years) and short-term (up to 20 years) trigger values for heavy metals and metalloids in irrigations water; the soil cumulative contaminant loading limit (identified as the CCL) triggers for heavy metals and metalloids are also presented in this table.

The relevant criteria for both human health and environmental concerns are presented in Table 2. Additionally, the criteria adopted for this investigation are indicated.

TABLE 2 Criteria for Groundwater Quality Assessment (mg/L)							
Analyte	Australian Drinking Water Guidelines (2011) ^{##}		ANZECC (2000) Table 3.4.1: Trigger Values for the Protection of 95% of Species in Freshwater	ANZECC (2000) Table 4.2.10: Agricultural irrigation LTV, STV and CCL triggers for heavy metals and metalloids			Adopted Criteria
	Aesthetic	Health		CCL (kg/ha) ^a	LTV ^b	STV ^c	
pH	6.5 – 8.5	-	6.5 – 7.5	-	-	-	6.5 – 7.5
TDS	500	-	-	-	-	-	500
Sodium	180	-	-	-	-	-	180
Chloride	250	-	-	-	-	-	250
Sulphate	250	500	-	-	-	-	500
Arsenic (total)	-	0.007	-	20	0.1	2.0	0.007
Arsenic (As III)	-	-	0.024	-	-	-	0.024
Arsenic (As V)	-	-	0.013	-	-	-	0.013
Cadmium	-	0.002	0.0002	2	0.01	0.05	0.0002
Chromium (total)	-	-	-	-	0.1	1	0.1
Chromium (Cr VI)	-	0.05	0.001 ^A	-	-	-	0.001
Copper	1	2	0.0014	140	0.2	5	0.0014
Iron	0.3	-	-	-	0.2	10	0.3
Lead	-	0.01	0.0034	260	2	5	0.0034
Manganese	0.1	0.5	1.9	-	0.2	10	0.1
Mercury	-	0.001	0.0006 [*]	2	0.002	0.002	0.0006
Nickel	-	0.02	0.011	85	0.2	2	0.011
Silver	-	0.1	0.00005	-	-	-	0.00005
Zinc	3	-	0.008	300	2	5	0.008

Notes: ^{##} NHMRC 2011

^A Figures may not protect key species from chronic toxicity

^{*} Inorganic form of mercury

- No criteria currently available

^a Suggested soil cumulative contaminant level (CCL) (kg/ha)

^b Long-term trigger values (LTV) in irrigation water (long-term use – up to 100 years (mg/L)

^c Short-term trigger values (STV) in irrigation water (long-term use – up to 20 years (mg/L)

4.0 FIELDWORK

4.1 Overview of Scope of Works

Table 3 provides an overview of the work completed under the conditions of the contract.

Note: The base of the concrete slab in the floor of the carriage was used as the reference point for depth, consistent with CMJA's investigation in 2006.

TABLE 3 Overview and Timetable of Fieldwork		
Date	Event	Comments
15 November 2011	Camera survey of West Cage	The camera run terminated at 1176.3 metres depth due to an obstruction in the cage shaft; blockage appeared to be corrugated iron mesh, which is likely to have dislodged from the wall of the shaft. The water table was encountered at 724.4 metres depth. The obstruction previously identified at 302.5 metres depth was identified, however, it did not halt the camera. Other previously identified obstructions at 666.1 and 669.5 metres depth were no longer evident.
	Geophysical logging of West Cage	Fluid resistivity and temperature profile of the water column was conducted. Logging was terminated at 1176.3 metres depth (due to the obstruction in the shaft) and was rerun when the instruments were withdrawn from the shaft.
	Groundwater sampling of West Cage	A groundwater sampling run of West Cage was conducted. Groundwater samples were collected from the top (at about 780 metres depth), from the middle (about 970 metres depth), and at the base of the accessible water column (1160 metres depth).
	Transport groundwater samples to South Mine for overnight storage	The groundwater samples were transported to the South Mine office, where they were stored and refrigerated overnight.
16 November 2011	pH measurement of groundwater samples.	The pH of each groundwater sample was measured using a calibrated TPS FLMV90 multi-parameter meter.
	Forwarded groundwater samples to NATA accredited laboratory for analysis	Samples were checked and repacked within an insulated ice chest before being dispatched to a NATA accredited laboratory by courier; samples arrived and were processed on 17 November 2011.

4.2 Camera Surveys of the No. 3 Shaft

A camera survey of the No.3 Shaft (West Cage) was conducted on 15 November 2011 by Mr Johnny Woods of NSW Office of Water (NOW).

The camera used during the survey was specially designed for use within 100 to 200 millimetre diameter boreholes and groundwater wells, and had a pressure rating of up to 1500 metres head of water. Given the camera's intended function, it only provided down-hole camera views in real time and could not swivel or view particular sections of interest.

The camera survey of the West Cage began at 9:30am on 15 November 2011. The camera was lowered into the shaft at a rate of about 22 metres per minute, although the rate slowed significantly when the water table was intercepted. The base of the concrete slab in the floor of the carriage was used as the reference point for depth.

Note: It was evident that water was entering the shaft at various levels between the reference point (surface) and the water table, as water droplets were observed falling down the shaft.

The obstruction identified in 2006 at 302.5 metres depth was visible (either a girder or piece of corrugated iron), however, it did not halt the survey. Other previously identified obstructions at 666.1 and 669.5 metres depth were no longer visible.

The water table was intercepted at approximately 724.4 metres depth. Based on this water level measurement and the water level measurement reported in 2006, the elevation of the water table appears to have increased by 167 metres.

Note: Once the camera entered the water, image resolution declined significantly, possibly owing to the amount of suspended solids in the water.

The survey of the shaft proceeded unhindered until a blockage was encountered at 1176.3 metres depth. The blockage appeared to be a piece of corrugated iron mesh that had been dislodged from the wall of the shaft. Unfortunately, the blockage was sufficient to halt the survey, and the camera was subsequently withdrawn from the shaft.

4.3 Geophysical Profiling of the No.3 Shaft

Geophysical logging of the No. 3 Shaft was carried out by NOW under the supervision of CMJA. Similar to the camera survey, access to the shaft was gained through the floor of the West Cage carriage, with the logging runs consisting of two combined fluid temperature and resistivity profiles.

Note: The temperature tool is rated to 70° Celsius and the Resistivity tool to 200 ohm metres.

The first run was carried out at 11:15am on 15 November 2011. The instruments were lowered into the water column at approximately 8 metres per minute, and the run was terminated at 1177.55 metres depth (i.e. about 453 metres below the water table).

A change in water chemistry was evident at approximately 758 metres depth, where it is believed that fresh water (as seen entering the shaft) intercepted more saline groundwater.

Once the results of the run had been reviewed, a second geophysical run was carried out when the instruments were being withdrawn from the water column, in order to confirm the results of the first survey.

Note: An additional geophysical run was conducted while the samples were being collected.

During each run, the following measurements were recorded:

- Fluid resistivity (recorded in units of ohm-metres),
- Induction conductivity (recorded as millisiemens per metre – mS/m),
- Temperature (recorded as °C),
- Differential temperature (recorded as temperature change in °C), and
- Depth (recorded as metres).

Information was continually displayed on a floating chart, and was recorded at the end of each run. Graphical logs for each geophysical run are presented on the logs accompanying this report.

4.4 Sample Collection and Handling

Groundwater sampling began at 2:15pm on 15 November 2011. The sampling was carried out by attaching HydraSleeve™ sample bladders at selected intervals to the wireline cable of the logging truck and then lowering the bladders into the shaft. The sample locations were selected based on:

- the geophysical profile of the water column;
- the water table elevation; and
- the (accessible) depth of the shaft.

Bladders were attached to the cable at both the top and the bottom of each bladder using polyethylene cable ties, and further held in place by duct tape. The bladders were placed at intervals that would correspond to the top, middle and bottom of the accessible water column (i.e. depths of about 780, 970 and 1160 metres depth RL). In total, nine sample bladders were used – three for each of the three sample locations.

The sample bladders were attached to the cable at the appropriate locations as the cable was gradually lowered to 1176.3 metres depth, where the bladders were allowed to equilibrate with the respective water pressures. When sufficient time had elapsed, the wireline was withdrawn from the shaft and the samples collected from the water column; it is the upward motion during the withdrawing of the wireline cable that opens the bladder and allows the sample to be collected.

When the bladders emerged from the shaft, they were punctured with the sample straw supplied with each bladder.

Note: A separate sample straw was used for each sample location.

Samples were then placed directly into the appropriate laboratory-supplied pre-treated containers and then within an insulated cool box; samples for heavy metals were filtered through a 0.45 micrometre membrane prior to being placed within the appropriate (unpreserved due to transport requirements) sample bottle.

Disposable gloves were used for sample collection and handling, with a new pair used for each sample.

Sample preservation and containers are described below in Table 4; further information regarding the Hydrasleeve™ bladders and their use in the environmental industry is provided in Appendix C.

TABLE 4 Sample Preservation								
Bottle Type ^π	Preservative	Field Filtered	Analyte					
			TSS ^λ , TDS ^π	Anions ^α	Cations ^β	Sulphide	Metals ^ψ - Dissolve	Oil and Grease
1-litre polyethylene	Nil	No	✓	✓	✓			
250-ml ^π polyethylene	Zn(O ₂ CCH ₃) ₂ ^φ + NaOH ^ε	No				✓		
125-ml polyethylene	Nil [‡]	Yes ^κ					✓	
1-litre glass bottle	H ₂ SO ₄	No						✓

Notes: ^π supplied and pre-treated by the laboratory
^λ total suspended solids
^π total dissolved solids
^α chloride, sulphate, carbonate and bicarbonate
^β calcium, magnesium, sodium and potassium
^ψ arsenic, cadmium, chromium (total), trivalent chromium, hexavalent chromium, copper, iron, lead, manganese, mercury, nickel and silver
^φ zinc acetate
^ε sodium hydroxide (added to sample bottles on site by CMJA)
[‡] nitric acid was not permitted to be transported by the airline, and was required to be added when the laboratory received the samples.
^κ sample filtered through a 0.45 micron membrane

All samples were immediately placed into an insulated cool-box and transported to the South Mine office for overnight storage within a refrigerated unit. The samples were cushioned using bubble-wrap.

The following morning, the samples were re-packed in insulated cool-box, which was filled with ice to maintain the temperature at less than or equal to 4°C. The lid of the cool-box was then taped shut and a security seal placed over the lid and side.

A courier then transported the samples directly to the Australian Laboratory Services Pty Ltd (ALS) at Smithfield; chain-of-custody records were maintained throughout sampling and transportation. ALS is certified by NATA to undertake analysis of the selected analytes.

Samples were dispatched from Broken Hill on 16 November 2011 and arrived at the laboratory on 17 November 2011. Nominated employees from the laboratory documented confirmation of sample arrival and condition on the supplied chain-of-custody (COC) form. Copies of the completed COC forms and sample-receipt-advice returns are provided in Appendix D.

The water temperature and induction conductivity were measured during geophysical profiling of the West Cage. The pH of each water sample was measured at 8:30am on 16 November 2011, using a calibrated TPS FLMV90 multi-parameter probe.

4.5 QA and QC Procedures

During the collection of the groundwater samples, all work was conducted in accordance with industry-accepted standards and in accordance with CMJA's standard operating and quality assurance procedures. Field QC during the investigation consisted of the following:

- preparation of a sampling and analysis plan designed to meet the project objectives and data quality objectives;
- sample collection procedures appropriate to the analytes of concern;

- the appropriate storage of samples during collection and transportation;
- extraction and analysis of all samples within the relevant method holding times; and
- the selection of appropriate sampling methods and data quantitation limits to satisfy the project data quality objectives.

No equipment wash blank samples were collected or submitted for laboratory analysis, given that a new sample bladder was used for each sample; a duplicate sample was not collected due to the limited number of sample bladders available.

5.0 RESULTS

5.1 Geophysical Profiling

The geophysical works carried out during the investigation identified that the upper 34 metres of the water column composed of slightly fresher water (fluid resistivity measurements at about 0.30 ohm/m, while induction conductivity measurements were below 800 mS/m).

The remainder of the water column (i.e. from 758 to 1177 metres depth) was more saline, well mixed and uniform with little to no signs of any stratification of water quality differentiation with depth. Overall:

- Fluid resistivity measurements were consistent throughout the profile, slightly fluctuating between -0.18 and -0.20 ohm/m.
- Induction conductivity measurements were typically between 1200 and 1300 mS/m.
- The temperature of the water was approximately 29°C.

Within an open shaft a reasonable inverse qualitative relationship between fluid resistivity and induction conductivity would be expected, and this was found to be the case.

The original copies of the geophysical logs produced by NOW accompany this report.

5.2 Analytical Results

Results of the groundwater samples collected from the West Cage of the No. 3 Shaft are presented in Table 5; whilst copies of original laboratory reports are provided in Appendix E.

TABLE 5 Field Parameters and Analytical Results West Cage, No. 3 Shaft, North Mine						
Analyte	Units	LOR	Adopted Criteria	WC: 780	WC: 970	WC: 1160
Physio-chemical Parameters						
pH	pH units	0.01	6.5 – 7.5	6.91	6.68	6.63
Electrical conductivity ^p	μS/cm	0.1		≈ 12,972	≈ 12,833	≈ 12,698
Temperature	°C	0.1		28.9	28.9	28.9
TDS and TSS						
Total Dissolved Solids	mg/L	5	500	6470	8200	8610
Total Suspended Solids	mg/L	5		98	32	33
Major Anions and Cations						
Bicarbonate Alkalinity as CaCO ₃	mg/L	1		76	67	67
Carbonate Alkalinity as CaCO ₃	mg/L	1		<1	<1	<1
Hydroxide Alkalinity as CaCO ₃	mg/L	1		<1	<1	<1
Total Alkalinity as CaCO ₃	mg/L	1		76	67	67
Sulfate as SO ₄	mg/L	1	500	2140	2620	2560
Chloride	mg/L	1	250	1660	2220	2780
Calcium	mg/L	1		518	682	728
Magnesium	mg/L	1		168	214	238
Potassium	mg/L	1		48	62	67
Sodium	mg/L	1	180	1390	1690	1870
Heavy Metals						
Arsenic	mg/L	0.001	0.007	0.073	0.099	0.098
Cadmium	mg/L	0.0001	0.0002	0.0101	0.0092	0.0101
Chromium	mg/L	0.001	0.1	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.0014	0.005	0.006	0.006
Iron	mg/L	0.05	0.3	23.8	29.7	29
Lead	mg/L	0.001	0.0034	0.082	0.167	0.198
Manganese	mg/L	0.001	0.5	107	112	112
Nickel	mg/L	0.001	0.011	0.151	0.171	0.171
Silver	mg/L	0.001	0.00005	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	0.008	35.7	38.8	39
Mercury	mg/L	0.0001	0.0006	<0.0001	<0.0001	<0.0001
Trivalent Chromium	mg/L	0.01		<0.01	<0.01	<0.01
Hexavalent Chromium	mg/L	0.01	0.001	<0.010	<0.010	<0.010
Sulfide						
Sulfide as S ²⁻	mg/L	0.1		<0.1	<0.1	<0.1
Ionic Balance						
Total Anions	meq/L	0.01		92.9	118	133
Total Cations	meq/L	0.01		101	127	139
Ionic Balance	%	0.01		4.36	3.36	2.17
Oil and Grease						
Oil and Grease	mg/L	5		<5	<5	<5

Notes: LOR limit of reporting

^p Determined from the fluid resistivity values measured during geophysical profiling and cross-checked against TDS concentrations for each of the samples collected during the project

μS/cm microsiemens per centimetre

mg/L milligrams per litre

meq/L milliequivalents per litre

From the results presented in Table 5, it can be seen that relative uniformity exists between each of the samples collected from the No. 3 Shaft, supporting the results of the geophysical profiling. The samples show that the water profile (between 780 and 1160 metres) is well mixed and not stratified.

Concentrations of manganese, iron and zinc were significantly above the adopted criteria for all samples submitted for analysis, reflecting the nature and occurrence of mineralisation in the area. Specifically:

- The difference in manganese concentrations between samples was negligible, ranging from 107 mg/L (WC:780) to 112 mg/L (WC:970 and WC:1160).
- The concentration of manganese in groundwater has increased since CMJA's previous investigation in 2006, where the maximum concentration reported was 68.1 mg/L at 890 metres depth.
- The difference in iron concentrations between samples was negligible, ranging from 23.8 mg/L (WC:780) to 29.7 mg/L (WC:970).
- Iron concentrations have slightly decreased since 2006 (minimum concentration of 30.6 mg/L at 890 metres depth), and there no longer appears to be a relationship between iron concentration and depth.
- The concentrations of zinc slightly increased with depth, ranging from 35.7 mg/L (WC:780) to 39 mg/L (WC:1160).
- Zinc concentrations have significantly increased since 2006 (maximum concentration of 12.2 mg/L at 1030 metres depth).

The high concentration of manganese in each of the samples is thought to reflect the abundance of manganese-rich rocks and minerals associated with ore lenses of the Broken Hill Lode.

As mentioned in Section 2.5 of this report, mineralisation at Broken Hill is hosted within a wide range of rock types including quartz-garnet gneisses and schists and quartz-spessartine rock – a quartz and manganese rich garnet rock which is commonly referred to as garnet sandstone, whilst rhodonite – a manganese silicate mineral – is common gangue mineral associated with economic ore horizons. Similarly, the high concentrations of iron in the samples are not considered to be surprising, given the abundance of available iron in a wide variety of minerals evident in the Broken Hill Lode; such minerals include pyrite (FeS_2), sphalerite (Fe, ZnS) – which is particularly iron-rich in the Broken Hill area, pyrrhotite (an iron sulphide), chalcopyrite (CuFeS_2) and arsenopyrite (FeAsS).

The high concentrations of iron in all samples analysed are consistent with the correspondingly high concentrations of manganese. Geochemically, both of these metals behave in relatively similar ways in groundwater systems and are soluble over quite a large range of pH and redox values.

The high concentrations of zinc in each of the samples is thought to reflect the high zinc grades and accompanying presence of sphalerite amongst the Broken Hill Lode; it is understood that sphalerite was never a key mineral of ore production at the North Mine, with the emphasis of mine operations placed on chasing out the high-grade galena lenses of the lode.

Other heavy metals, i.e. arsenic, cadmium, copper, lead and nickel, were reported at concentrations above the adopted criteria. Although these results are not entirely comparable to the 2006 results (based on different sampling intervals), concentrations of arsenic appear to have slightly decreased, while concentrations of cadmium, copper, lead and nickel appear to have slightly increased.

Consistent with previous results, no concentrations of chromium (either the trivalent or hexavalent species), mercury, silver, sulphide or oil and grease were detected at concentrations greater than the limit of reporting for each sample.

The low resistivity of the water column observed during geophysical logging of the West Cage is reflected in the high concentration of TDS in each of the samples. As presented in Table 5:

- TDS concentrations increased with depth and ranged from 6470 mg/L (WC:780) to 8610 mg/L (WC:1160),
- Major anion and cation concentrations were typically of the order of 92.9 to 139 milliequivalents per litre (meq/L).
- Sodium is considered to be the dominant cation for all samples, with a maximum concentration of 1870 mg/L (WC:1160).
- Chloride and sulphate are considered to be the dominant anions for all samples, with maximum concentrations of 2780 mg/L (WC:1160) and 2620 mg/L (WC:970), respectively.
- Concentrations of bicarbonate, calcium, magnesium and potassium were relatively low.
- Concentrations of carbonate and hydroxide were below the limit of reporting and would not be expected at the measured pH.

The sulphate present is likely to be derived from the oxidation of abundant sulphide minerals associated with the lode and surrounding geology.

These concentrations correlate well with the measurements of fluid resistivity recorded during the geophysical profiling and are consistent with those results previously reported by CMJA. For comparative purposes, the dissolved solids content of seawater is about 35,000 mg/L.

A trilinear diagram showing the composition of the three samples obtained during this investigation is shown in Figure 4.

The pH of the groundwater indicates that it is slightly acidic to neutral. Given the abundance of sulphate throughout the water column and the oxidised nature of the groundwater (evident by the abundance of sulphate and lack of discernible sulphide), low pH conditions (acidic) were expected. However, the relatively neutral pH could be indicative of pH buffering by carbonate minerals or the continuing dilution of groundwater in the shaft by relatively fresh groundwater ingress.

6.0 GROUNDWATER USE AND DISPOSAL OPTIONS

Consideration of re-use potential was part of CMJA's original scope of works, and this section has been included for completeness. Water of almost any quality can be treated to make it suitable for almost any purpose – at a price. In normal circumstances, treatment of water of the quality encountered in the North Mine would be considered uneconomic.

However, circumstances at Broken Hill are not normal, so all options could at least be considered.

6.1 Overview of the Nature and Behaviour of Iron and Manganese

From the results presented in Section 4.2, it can be seen that the total salinity together with iron and manganese, and less notably zinc concentrations, are the largest issues when trying to ascertain suitable reuse or disposal options for the water from the North Mine. Characteristics of each of these metals are discussed below.

Iron occurs commonly in soil and rocks as the oxide, sulphide and carbonate minerals. In water, it is present as ferric (Fe^{3+}) [oxidised] or ferrous (Fe^{2+}) [reduced] ions or ion complexes. In aerated surface waters, iron is often complexed with organic matter such as humic material, or adsorbed onto suspended matter. In uncontaminated surface waters, dissolved iron concentrations are usually less than 1 mg/L, but, water supplied through rusting iron pipes can have concentrations of 5 mg/L or higher.

In oxygen-depleted ground water, iron concentrations of up to 100 mg/L have been recorded. Iron has a taste threshold of about 0.3 mg/L in water, and becomes objectionable above 3 mg/L. High iron concentrations give water an undesirable rust-brown appearance and can cause staining of laundry and plumbing fittings, fouling of ion-exchange softeners, and blockages in irrigation systems: growths of iron bacteria, which concentrate iron, may cause taste and odour problems and lead to pipe restrictions, blockages and corrosion.

Manganese is present in the environment in the divalent (Mn^{2+}), tetravalent (Mn^{4+}), and heptavalent (Mn^{7+}) states. Most of the divalent compounds are soluble in water; the most common tetravalent compound, manganese dioxide, is insoluble, but the heptavalent permanganate is soluble.

Zinc is widely distributed and occurs in small amounts in almost all rocks, commonly as the sulphide sphalerite. In surface and ground waters, the zinc concentrations from natural leaching is usually less than 0.01 mg/L, however tap water can contain much higher concentrations as a result of corrosion of zinc-coated pipes and fittings; concentrations in galvanised iron rainwater tanks are typically 2 mg/L to 4 mg/L but have been reported as high as 11 mg/L.

Taste problems can occur if the zinc concentration in drinking water exceeds 3 mg/L. Water with zinc concentrations in excess of 5 mg/L tends to be opalescent and develop a greasy film when boiled; it also has an undesirable dry metallic taste.

Uncontaminated rivers and streams generally have low concentrations of manganese, ranging from 0.001 mg/L to 0.6 mg/L. High concentrations may occur in polluted rivers or under anoxic conditions such as at the bottom of deep reservoirs or lakes, or in groundwater. At concentrations exceeding 0.1 mg/L manganese imparts an undesirable taste to water and stains plumbing fixtures and laundry, and at concentrations of 0.02 mg/L it will form a coating on pipes that can slough off as a black ooze; some nuisance microorganisms can also concentrate manganese and give rise to taste, odour and turbidity problems in distribution systems.

In general, oxygen-rich water will have only low levels of iron and manganese as both iron and manganese react with oxygen to form compounds which prefer to precipitate rather than stay in

dissolved state. Surface water and shallow groundwater usually have enough dissolved oxygen to maintain iron and manganese in an insoluble state, whilst in surface water iron and manganese are most likely to be trapped within suspended organic matter particles.

Waters that do not have contact with the atmosphere tend to be low in oxygen. Iron and manganese carbonates in an oxygen-poor environment are relatively soluble and can cause high levels of dissolved iron and manganese. However, if iron is associated with sulphur as iron sulphide rather than iron carbonate, dissolved iron remains low. Dissolved oxygen generally decreases with depth, so these types of conditions are more likely to occur in deep wells or the shafts evident along the alignment of the Broken Hill Lode where any available oxygen would be consumed by reactions with sulphides; sometimes oxygen-poor conditions can also occur in relatively shallow wells that have stagnant water with very slow turnover.

6.2 Untreated Reuse or Disposal of the North Mine Water

A brief assessment of whether the water in its current condition could be used is provided in the paragraphs below. The assessment looks at whether it is possible to dispose of the water to Stephens Creek Catchment as potable water, pump the water to Imperial Lake just to the north-east of the North Mine, and finally use the water for long and short-term irrigation purposes.

For the assessment of potential human health issues relating to the consumption of untreated water from the North Mine, it is considered that the appropriate criteria are those presented within the Health Guidelines listed in the *Australian Drinking Water Guidelines* (2011). These levels relate specifically to water that is to be used for human consumption, and although they do not represent mandatory standards for the quality of water for human consumption, they do offer a framework for identifying acceptable water quality.

For the assessment of potential environmental impacts arising from the interaction of untreated water from the North Mine with freshwater aquatic ecosystems (such as Imperial Lake), it is considered that the appropriate criteria are those trigger values set for the protection of 95 per cent of species in fresh water and listed in Table 3.4.1 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

For the assessment of issues relating to the use of the water for irrigation purposes, it is considered that the appropriate criteria are those values presented in Table 4.2.10 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). The values presented in this table represent long-term (up to 100 years) and short-term (about 20 years) trigger values for heavy metals and metalloids in irrigation water; the soil cumulative contaminant loading limit (identified as the CCL) triggers for heavy metals and metalloids are also presented in this table.

Copies of the relevant criteria for both human health and environmental concerns are presented in Appendix G; values included are those values applying to slightly-moderately disturbed systems, and have been derived for use in assessing surface waters. In the absence of specific levels for groundwater, the surface-water trigger values have been used; no criteria are currently available for the parameters that are absent in Appendix G yet included in the analytical schedule used during the groundwater sampling and analysis program.

On the basis of the analytical results presented in Section 4.2 it is clear that the water in the North Mine will require some sort of treatment before any reuse options can realistically be considered. It can be clearly seen that concentrations of all of the heavy metals included in the analytical suites, particularly manganese, iron and zinc, exceed their relevant threshold and trigger levels presented in Appendix G, with numerous exceedances also noted for several of the less abundant heavy metals including arsenic, lead and nickel.

High sodium, chloride and sulphate concentrations (as noted by the low fluid resistivity and high TDS concentrations) and are also of concern.

Even use for dust suppression would need to be carefully considered, given the salt accumulation on roads and consequent corrosion hazards. Dust suppression on non-traffic areas would be possible without treatment.

6.3 Water Treatment Options

There are a number of commercial treatment processes that remove manganese, iron and zinc from water and that are expected to also assist in removing some of the less abundant metals from the water. Iron can be effectively removed by settlement or by using aeration, oxidation with chlorine, pH adjustment or lime softening, followed by coagulation and settlement or filtration.

Converting soluble forms to insoluble precipitates followed by filtration can reduce manganese concentrations in water. Chlorine can be used to oxidise some forms of manganese whilst lime softening at high pH may also be effective in removing some forms.

Treatment options for high zinc concentrations are much simpler methods such as alum coagulation at pH 6.5 to pH 7 (about 30% removal) or by lime softening at pH 9.5 to pH 10 (roughly 60% removal).

Treatment processes for the less abundant metals and salinity include:

- coagulation and lime-softening for the partial or complete removal of arsenic, lead and cadmium, the later with ferric chloride;
- co-precipitation of nickel during the treatment of water for high iron and manganese concentrations; and
- desalination via reverse osmosis or electrodialysis/electrodialysis reversal for the treatment of water for salinity (in this instance high chloride, sodium and sulphate concentrations).

Given the very high concentrations of iron and manganese, a combination of treatment processes is likely to be required if Perilya wishes to pursue water reuse options.

Some of the abovementioned treatment options are further discussed below.

6.3.1 Oxidation

Before iron and manganese can be filtered, they need to be oxidised to a state in which they can form insoluble complexes. Oxidation involves the transfer of electrons from the iron, manganese, or other chemicals being treated to the oxidising agent. Ferrous iron (Fe^{2+}) is oxidised to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $\text{Fe}(\text{OH})_3$; reduced manganese (Mn^{2+}) is oxidised to (Mn^{4+}), which forms insoluble MnO_2 .

The most common chemical oxidants in water treatment are chlorine, chlorine dioxide, potassium permanganate, and ozone. Oxidation using chlorine or potassium permanganate is frequently applied in small groundwater systems where the dosing is relatively easy, requires simple equipment, and is fairly inexpensive; chlorination is widely used for oxidation of divalent iron and manganese.

As an oxidant, potassium permanganate (KMnO_4) is normally more expensive than chlorine and ozone, but for iron and manganese removal, it has been reported to be as efficient and it requires considerably less equipment and capital investment; the dose of potassium permanganate, however, must be carefully controlled.

Ozone may be used for iron and manganese oxidation.

A low-cost method of providing oxidation is to use the oxygen in air as the oxidising agent in a tray aerator. Water is simply passed down a series of porous trays to provide contact between air and water; no chemical dosing is required, which allows unattended operation; a complication is that the rate of reaction between oxygen and manganese is very slow below pH values of 9.5.

6.3.2 Filtration

Chemical oxidation followed by filtration is the main method of iron and manganese removal when concentrations exceed 10 mg/L.

In general, manganese oxidation is more difficult than iron oxidation because the reaction rate is slower. A longer detention time (10 to 30 minutes) following chemical addition is needed prior to filtration to allow the reaction to take place. A number of specialist filtration media are available for the removal of iron and manganese.

6.3.3 Desalination

There are many technologies available to desalinate (remove salt from) saline or brackish water. Only those technologies that are likely to be economically viable for improving the quality of brackish groundwater at Broken Hill are discussed below.

Reverse Osmosis

Reverse osmosis (RO) is a membrane process in which solutions are desalinated or concentrated using relatively high hydraulic pressure as the driving force across a membrane that is semi-permeable, allowing the fluid that is being purified to pass through it, while rejecting the contaminants that remain. The higher the pressure, the greater the driving force. As the concentration of the fluid being rejected by the membrane increases, the driving force required to continue the process increases. RO is also known as hyperfiltration.

Most RO technology uses a process known as crossflow to allow the membrane to continually clean itself. As some of the fluid passes through the membrane the rest continues downstream, sweeping the rejected species away from the membrane.

RO is capable of rejecting bacteria, salts and other constituents that have a molecular weight of greater than 150 to 250 daltons. The separation of ions with RO is aided by charged particles. This means that dissolved ions that carry a charge, such as salts, are more likely to be rejected by the membrane than those that are not charged, such as organics. The larger the charge and the larger the particle, the greater the likelihood of rejection. Typically, the product of RO plants has a salinity of less than 500 mg/L TDS.

RO is a maturing technology and is very scalable – the range extends from units with capacities starting at 400 litres per day, to very large plants capable of supplying major towns. Large RO plants utilising brackish groundwater feed have been in use in the Middle East since the mid-1980s, and most of the installed desalination capacity in Australia, including the major plants in Sydney, the Gold Coast and Perth, and those under construction/commissioning in Melbourne and Adelaide, is RO. Recently, small package units directly coupled to photovoltaic (solar electric) cells have become available. Groundwater RO feed has a number of issues not apparent in surface water sources, including iron and hydrogen sulphide fouling. Brine disposal is also a significant issue in inland areas.

RO is used to treat groundwater extracted from the Great Artesian Basin to make it suitable for potable use in the town of Roxby Downs. The unit cost of water supply in Roxby Downs is about Aus\$2.40 per kilolitre; costs quoted in product literature are often less – about Aus\$1.70 per kilolitre.

Electrodialysis/Electrodialysis Reversal

Electrodialysis (ED) also involves the movement of water through a membrane. Instead of pressure, a low-voltage DC electric field supplies the motive force. An ED cell contains compartments separated by membranes that are permeable to either anions or cations. Under the influence of the electric field, ions migrate through the appropriate membrane, leaving reduced-salinity water behind.

Electrodialysis Reversal (EDR) is a relatively recent enhancement that involves a reversal of water flow in order to break up and flush out scales and slimes.

Economic factors have limited the uptake of ED technology. It is really only a practical proposition for brackish waters with a salinity less than about 12,000 mg/L TDS. However, ED requires less pre-treatment than RO, and EDR in particular is very competitive with RO for scaling waters with salinity less than 3000 mg/L TDS.

Table 6 provides a comparison of RO and ED advantages and disadvantages.

TABLE 6 Comparison of RO and ED Advantages and Disadvantages		
Technology	Advantages	Disadvantages
RO	<ul style="list-style-type: none"> Quick and cheap to build and simple to operate. There are few components; durable plastics and non-metal materials are mainly used – pre-treatment of the feedwater to prevent fouling of the membrane is the only potential problem. Can handle a large range of flow rates, from a few litres per day to 750,000 L/day for brackish water. The capacity of the system can be increased at a later date if required by adding on extra modules. High space/production capacity ratio, ranging from 25,000 to 60,000 L/day/m². Low energy consumption. Can remove other contaminants in the water as well as the salt. Low chemical consumption for cleaning purposes. No need to shut down the entire plant for scheduled maintenance due to the modular design of the plant. Rapid startup and shutdown. 	<ul style="list-style-type: none"> RO membranes are expensive and have a life expectancy of 2-5 years. High quality materials and equipment are required. An extensive spare parts inventory is necessary. There is a possibility of bacterial contamination. This would be retained in the brine stream, but bacterial growth on the membrane itself can cause the introduction of tastes and odours into the product water. Pre-treatment of the feedwater is required to remove particulates so that the membranes last longer. The plant operates at high pressures; mechanical failure of equipment may occur due to the high pressures used.
ED/EDR	<ul style="list-style-type: none"> High recovery ratio (85-94% for one stage). Can treat feedwater with a higher level of suspended solids. Pre-treatment has a low chemical usage. Energy usage is proportional to the salts removed, and not to the volume of water being treated. Membranes have a life expectancy of 7-10 years, which is longer than for RO. Membranes are not susceptible to bacterial attack or silica scaling. Scaling can be controlled whilst the process is on line; the membranes can also be manually cleaned. Can be operated at low to moderate pressure. 	<ul style="list-style-type: none"> Periodic cleaning of the membranes with chemicals is required (less with EDR). Leaks sometimes occur in the membrane stacks. Bacteria, non-ionic substances and residual turbidity are not removed by the system and can therefore remain in the product water.

The only beneficial use available without treatment would be dust suppression in non-traffic areas.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Given the analytical results presented in Section 5.2 of this report, it is clear that the groundwater entering the North Mine will require some sort of treatment before most reuse options become feasible.

It is evident that concentrations of all of the heavy metals included in the analytical suite, particularly those of manganese, iron and zinc, exceed the adopted criteria and trigger values relating to suggested untreated water disposal or reuse options. Specifically,

- manganese concentrations ranged from 107 mg/L (WC:780) to 112 mg/L (WC:970 and WC:1160),
- iron concentrations ranged from 23.8 mg/L (WC:780) to 29.7 mg/L (WC:970), and
- zinc concentrations ranged from 35.7 mg/L (WC:780) to 39 mg/L (WC:1160),

which is thought to reflect the nature and occurrence of mineralisation in the area.

Additionally, numerous exceedances were noted for several of the less abundant heavy metals including arsenic, lead and nickel.

The low resistivity of the water column observed during geophysical logging of the West Cage is reflected in the high concentration of TDS in each of the samples. Major anion and cation concentrations were typically of the order of 92.9 to 139 meq/L, with measured concentrations of TDS varying between 6470 and 8610 mg/L. These concentrations correlate well with the measurements of fluid resistivity recorded during the geophysical profiling works. In each sample, sodium is the dominant cation, while chloride and sulphate the dominant anions. The pH of the groundwater indicates that it is slightly acidic to neutral.

There are a number of commercial applications that can remove manganese, iron and zinc from water and that are expected to also assist in removing some of the less abundant metals from the water, including coagulation followed by filtration. Groundwater supplies with a high iron and manganese content can be treated to form iron precipitates using aeration, oxidation with chlorine, pH adjustment or lime softening.

Given the concentrations of iron, manganese and salinity, it is highly likely that a combination of water treatment methods will be required.

Undoubtedly, treatment of the volume of water estimated to be present in the workings would be expensive, and in most circumstances would simply be uneconomic. Unusual circumstances do however exist in Broken Hill, and a detailed appraisal of the economic viability of metal removal followed by desalination based on projected volumes generated by dewatering program would be worthwhile.

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C. M. Jewell & Associates Pty Ltd
Water and Environmental Management
ABN 54 056 283 295

Important Information About Your Environmental Site Assessment

These notes will help you to interpret your hydrogeological and Environmental Site Assessment (ESA) reports.

Why are ESAs conducted?

An ESA is conducted to assess the environmental condition of a site. It is usually, but not always, carried out in one of the following circumstances.

- As a pre-purchase assessment, on behalf of either purchaser or vendor, when a property is to be sold.
- As a pre-development assessment, if a property or area of land is to be redeveloped, or if its use is to change (for example, from a factory to a residential subdivision) – to meet a requirement for development approval.
- As a pre-development assessment of a 'greenfield' (undeveloped) site - to establish baseline conditions and to assess environmental, geological and hydrological constraints to the proposed development.
- As an audit of the environmental effects of an ongoing operation.

Each type of assessment requires its own specific approach. In all cases, however, the aim is to identify and if possible quantify the risks posed by unrecognised contamination. Such risks may be financial (for example, clean-up costs or limitations on site use), or physical (for example, health risks to site users or the public).

What are the limitations of an ESA?

Although the information provided by an ESA can reduce exposure to these risks, no ESA, however diligently carried out, can eliminate risks altogether. Even a rigorous professional assessment may not detect all contamination on a site. The following paragraphs explain why.

ESA 'findings' are professional estimates

The ground surface conceals a complex 3-dimensional subsurface environment. Subsurface materials, whether placed by geological processes or human activities, are always heterogeneous. Large variations in lithology and hydraulic properties can occur over short distances. Surface observation, and data obtained from boreholes and

test pits, can never give us a complete picture of the subsurface.

All data from sampling and laboratory testing must be interpreted by a qualified professional – a geologist, engineer or scientist. They then render an opinion - about overall subsurface conditions, the nature and extent of contamination, its likely impact on the proposed development, and appropriate remediation measures.

Interpretation and professional judgement are thus essential to the assessment process.

Accuracy depends on the scope of work

Site assessment identifies actual subsurface conditions only at those specific points where samples are taken and when they are taken. The accuracy of the entire process depends on sampling frequency and sampling methods - yet the extent of sampling and soil analysis must necessarily be limited.

Sampling generally targets those areas where contamination is considered to be most likely, on the basis of visual observation and the site's history. This approach does maximise the probability of identifying contaminants, but it may not identify contamination in unexpected locations or from unexpected sources.

No professional, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. For example, there may be contaminants in areas not surveyed or sampled; furthermore, they may migrate to areas that showed no signs of contamination at the time of sampling.

Conditions between sample locations can only be inferred – from estimates of geological and hydrogeological conditions, and from the nature and extent of identified contamination. Soil, rock and aquifer conditions are often variable, and so the distribution of contaminants across a site can be difficult to assess. Actual conditions in areas not sampled may differ from predictions.

The accuracy of an assessment is therefore limited by the scope of work undertaken.

Important Information About Your Environmental Site Assessment

Page 2

Statistical tools can be helpful, but the validity of conclusions still depends entirely on the degree to which the original data reflect site conditions.

Uncertainty is also inevitable when it comes to assessing chemical fate and transport in groundwater and surface water systems, and calculating human health and environmental exposure risks. It is inevitable, too, when estimating remediation performance and time frames.

Your CMJA report includes a statement of the uncertainty associated with this particular project; you should read it carefully.

We can offer solutions

We cannot prevent the unanticipated, but we can minimise its impact. For this reason we recommend that you retain CMJA's services through the remediation and development stages. We can identify differences from predicted conditions, conduct additional tests as required, and recommend solutions for problems encountered on site.

Don't rely on out-of-date information

Subsurface conditions are changed by natural processes and the activity of people. Your ESA report is based on conditions that existed at the time of subsurface exploration. Don't make decisions on the basis of an ESA report whose adequacy may have been affected by time. Speak with CMJA to learn if additional tests are advisable.

If things change, contact us

Every report is based on a unique set of project-specific factors. If any one of these factors changes after the report is produced, its conclusions and recommendations may no longer be appropriate for the site.

Your environmental report should not be used:

- if the nature of the proposed development is changed - for example, if a residential development is proposed instead of a commercial one;
- if the size or configuration of the proposed development is altered;
- if the location or orientation of the proposed structure is modified;
- if there is a change of ownership; or
- for application to an adjacent site.

To help avoid expensive problems, talk to CMJA. We will help you to determine how any factors that have changed since the date of the report may affect its recommendations.

Your ESA report is prepared specifically for you

Every hydrogeological study and ESA report is prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even for another consulting civil engineer. A report should not be used by anyone other than the client, and it should not be used for any purpose other than that originally intended. Any such proposed use must first be discussed with CMJA.

Beware of misinterpretation

Costly problems can occur if plans are based on misinterpretations of an ESA. These problems can be avoided if CMJA is retained to work with appropriate design professionals. We will explain the relevant findings and review the adequacy of plans and specifications.

Logs and laboratory data should not be separated from the report

Final borehole or test pit logs are developed by CMJA's environmental scientists, engineers or geologists, using field logs (assembled by site personnel) and laboratory evaluation of field samples. Our reports usually include only the final logs, which must not under any circumstances be redrawn for inclusion in other documents.

Similarly, our reports often include field and laboratory data, and laboratory reports. These data should not be reproduced separately from the main report, which provides guidance on their interpretation and limitations.

To reduce the likelihood of misinterpretation, only the complete report should be made available for the use of persons or organisations involved in the project, such as contractors. Consult CMJA before distributing reports, and we will assist with any additional interpretation that is required.

Always read responsibility clauses closely

To avoid misunderstandings, our report includes qualifying statements that explain the level of certainty associated with our findings and recommendations, and responsibility clauses that indicate where our responsibilities to clients and other parties begin and end.

These qualifying statements and responsibility clauses are an important part of your report. Please read them carefully. They are not there to transfer our responsibilities to others but to help all parties understand where individual responsibilities lie.

These notes were prepared by C. M. Jewell & Associates Pty Ltd (CMJA) using guidelines prepared by the National Ground Water Association (NGWA) and other sources.

Groundwater Quality Investigation - No. 3 Shaft, North Mine, Broken Hill

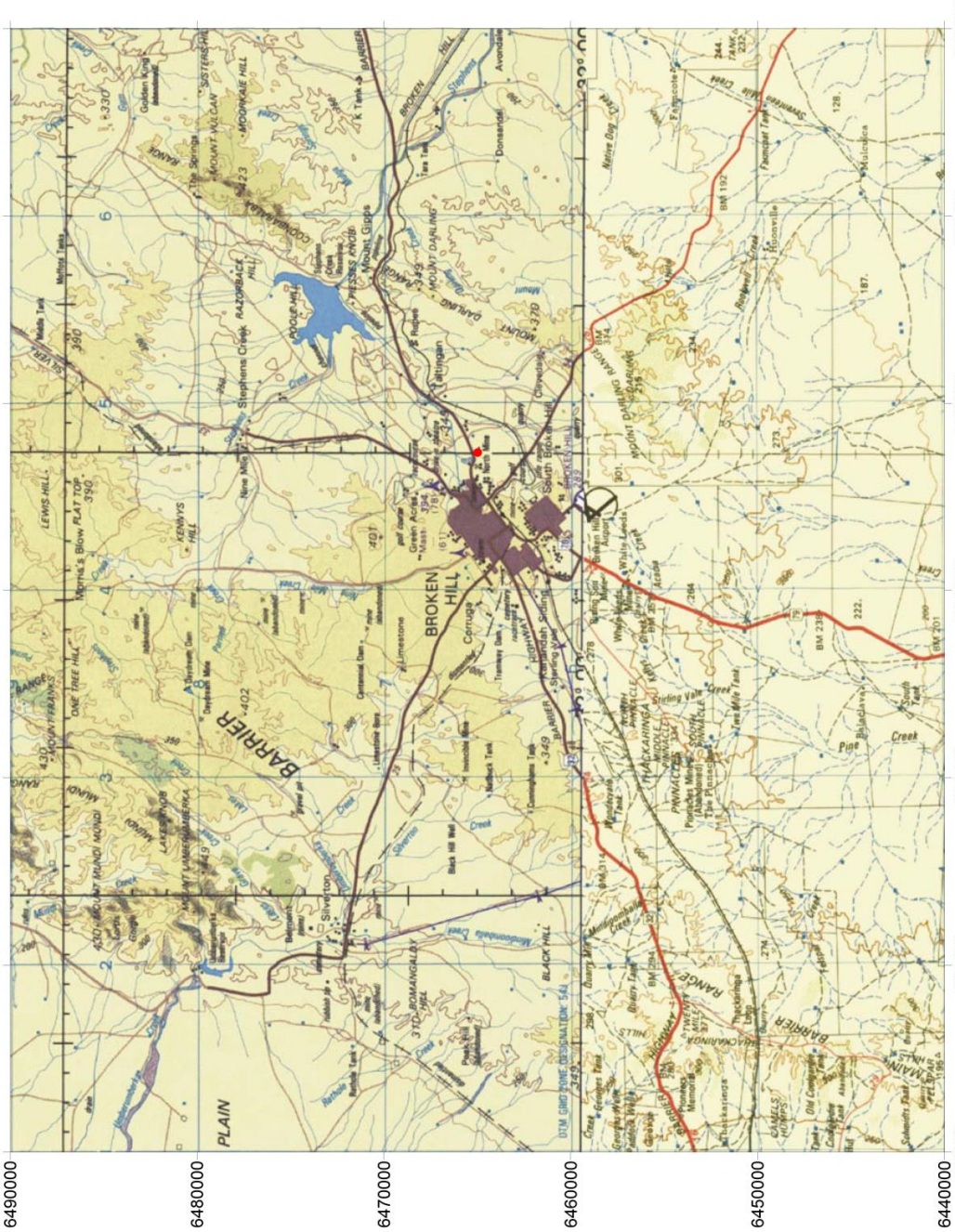


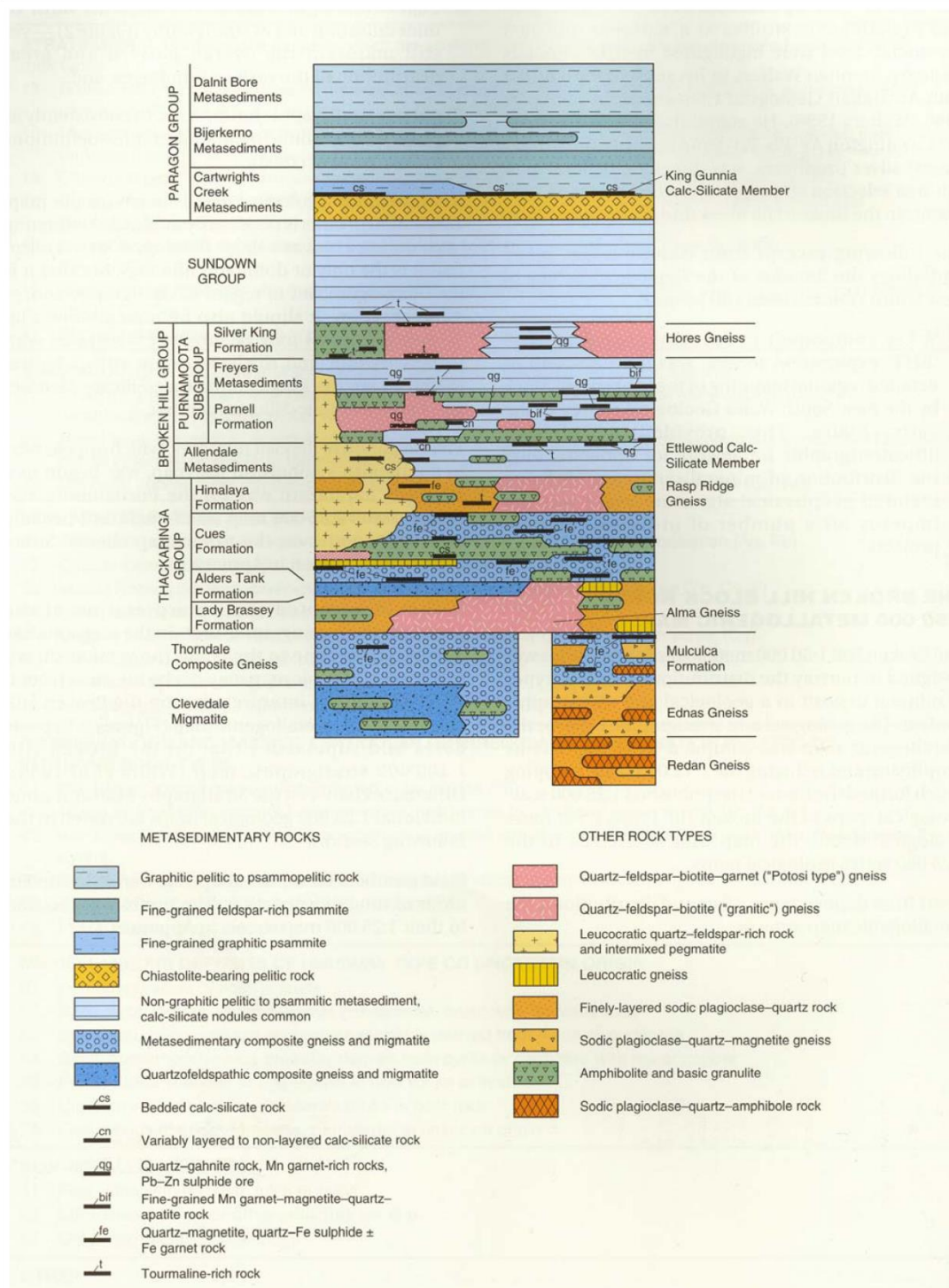
Figure 1
Local Setting

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Rev: 0

Date: 22-Nov-11

Author: LER

Figure 2
Generalised Stratigraphy of
the Willyama Supergroup

Groundwater Quality Investigation - No. 3 Shaft, North Mine, Broken Hill

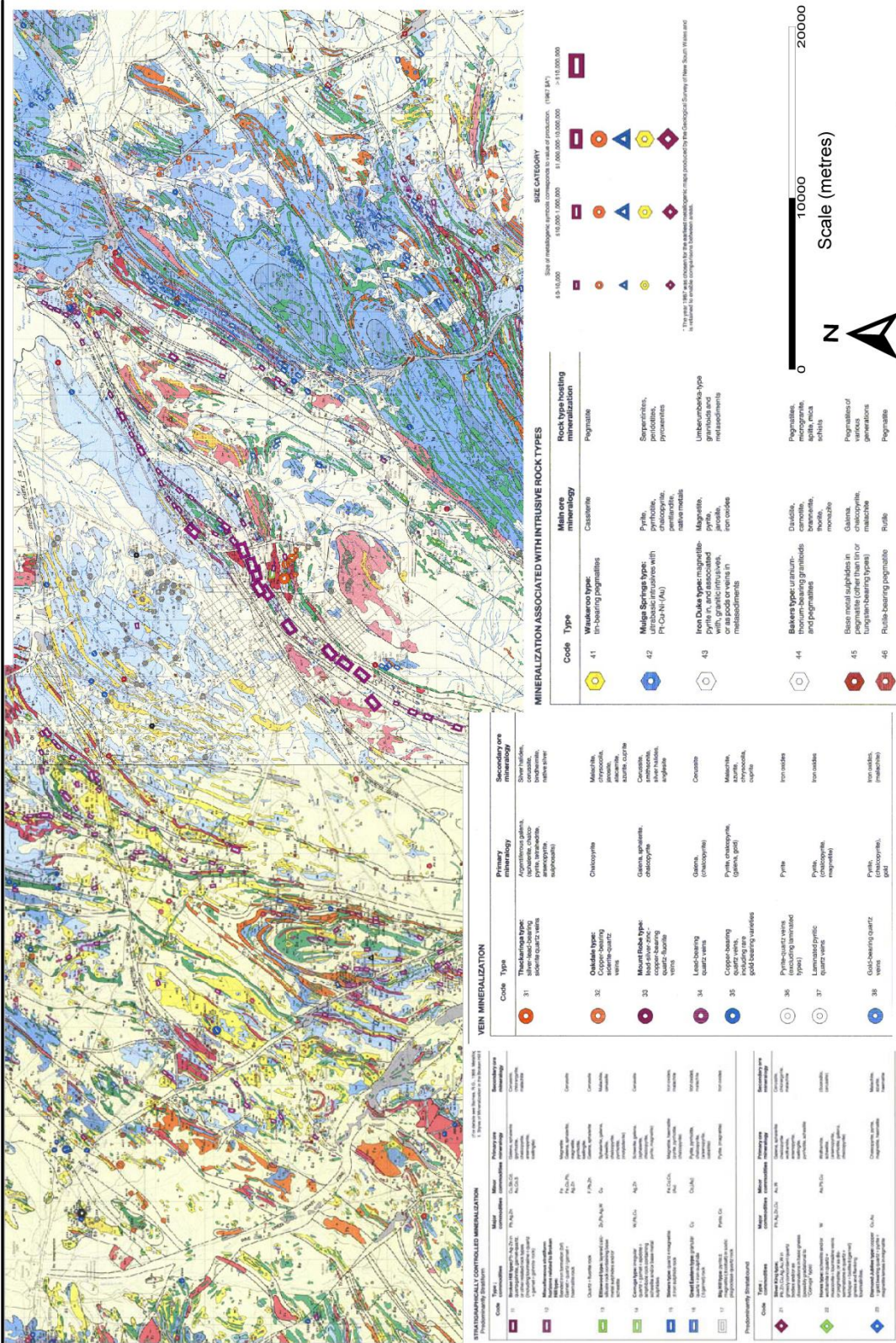
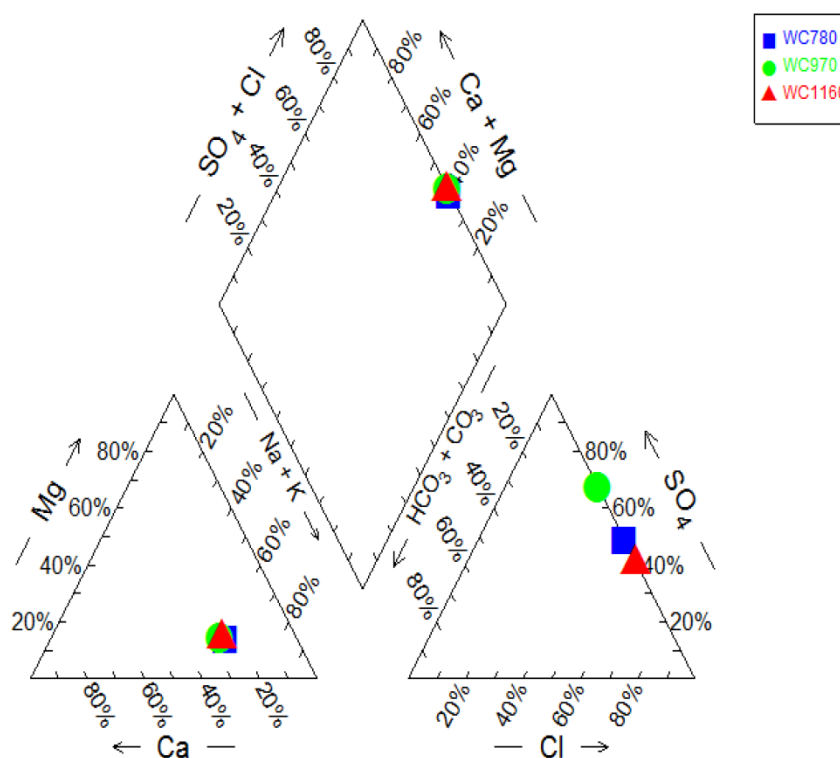


Figure 3
Geology and Mineralisation of the Broken Hill Area

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Date: 22-Nov-11
Author: LER

Figure 4
Trilinear Diagram
Water Composition



APPENDIX A
Borehole Summary Worksheet
for Borehole GW021882

CMJA

29-01-04;16:55

13/ 11

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

W021882

Converted From HYDSYS

License : 8081013984

Work Type : Bore
Work Status : (Unknown)
Construct. Method : (Unknown)
Owner Type : Private

Authorized Purpose(s)
STOCK

Intended Purpose(s)
STOCK

Commenced Date :
Completion Date : 01-Feb-1964

Final Depth : 67.10 m
Drilled Depth : 67.10 m

Contractor Name :
Driller :

Property : - FARMCOTE STATION
CWMMA : -
GW Zone : -

Standing Water Level :
Salinity : Stock
Yield :

ite Details

Site Chosen By

County
Form A : YANCOWINNA
Licensed : YANCOWINNA

Parish
invalid code
NIL

Portion/Lot DP
WLL 1389
LT DP

Region : 80 - MACQUARIE-WESTERN
River Basin : 425 - DARLING RIVER
Area / District :

CMA Map : 7233
Grid Zone : 54/2

REDAN
Scale : 1:100,000

Elevation :
Elevation Source : (Unknown)

Northing : 6457600
Easting : 556150

Latitude (S) : 32° 0' 58"
Longitude (E) : 141° 35' 40"

GS Map : 0043B1 AMG Zone : 54

Coordinate Source : GD, ACC.MAP

onstruction

Negative depths indicate Above Ground Level (H-Hole; P-Pipe; OD-Outside Diameter; ID-Inside Diameter; C-Cemented; S-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity

P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Result
1	Casing	Threaded Steel	-5.40	4.50	152			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBC Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
61.00	61.00	0.00 (Unknown)		42.70		0.32			Stock

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.83	1.83	Soil Red	Soil	
0.00	1.83	1.83	Mixed Rubble		
1.83	60.96	59.13	Granite Decomposed Some Limestone	Granite	
1.83	60.96	59.13	Quartzite Coloured	Quartzite	
60.96	67.06	6.10	Gravel Coarse Water Supply	Gravel	

Willigama

Remarks

*** End of GW021882 ***

Pratt To Clients: This raw data has been supplied to the Department of Land and Water Conservation (DLWC) by (drillers, licensees and other sources). The DLWC does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.



APPENDIX B

Groundwater Quality, Southern Leases

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TABLE 4 - GROUNDWATER CHEMISTRY - SOUTHERN LEASES, OCTOBER 1983
All concentrations in mg/l (ppm)

Drill-Hole No.	pH	Major Elements				TSS		Heavy Metals					Cr				Fe			
		Ca	Mg	Na	K	SO ₄	Cl	Ag	Cd	Cu	Mn	Pb	Zn	Cr	Fe	Fe	Fe	Fe	Fe	Fe
3	8.9	50	87	1240	34	360	1510	bld	bld	bld	0.062	bld	0.415	0.005	bld	bld	bld	bld	bld	bld
4	7.8	175	565	4240	41	2370	6010	bld	bld	bld	0.610	bld	0.610	0.010	0.165	bld	bld	bld	bld	bld
5	7.4	81	45	275	13	195	470	bld	bld	bld	0.900	.020	0.965	0.010	0.070	bld	bld	bld	bld	bld
8	6.9	520	350	1730	28	1620	3240	bld	0.020	bld	0.011	bld	1.475	0.020	0.060	bld	bld	bld	bld	bld
15	7.3	410	420	2030	28	2270	3540	0.010	bld	bld	0.445	bld	0.425	0.020	14.300	bld	bld	bld	bld	bld
16	6.7	640	320	1800	27	3290	2690	bld	0.045	bld	4.225	bld	6.650	0.015	0.145	bld	bld	bld	bld	bld
17	7.5	690	395	2170	32	2600	4000	0.010	0.005	bld	1.915	.100	0.850	0.020	0.130	bld	bld	bld	bld	bld
21	7.5	810	555	2930	27	2440	5780	0.010	0.025	bld	0.905	.320	0.875	0.025	0.115	bld	bld	bld	bld	bld
24	6.9	845	252	3730	75	4150	5700	0.005	0.010	bld	12.470	.060	2.060	0.020	3.740	bld	bld	bld	bld	bld
25	7.4	1400	2160	10400	41	3880	11300	0.040	0.220	bld	10.151	1.420	4.200	0.065	0.270	bld	bld	bld	bld	bld
Decant	-	800	116	2360	119	3055	3920	0.030	0.010	bld	12.150	.100	1.320	0.045	0.200	bld	bld	bld	bld	bld
Toe Drain	-	855	96	1930	103	2900	3340	0.035	0.010	bld	25.550	.390	1.360	0.035	0.175	bld	bld	bld	bld	bld

bld denotes below level of detection

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TABLE 5 - GROUNDWATER CHEMISTRY - SOUTHERN LEASES, JANUARY 1984
All concentrations in mg/l (ppm)

Drill-Hole No.	pH	Major Elements							TSS	Heavy Metals					
		Ca	Mg	Na	K	SO ₄	Cl	Ag		Cd	Cu	Mn	Pb	Zn	Cr
3	7.4	28	55	1380	39	565	1723	bld	bld	bld	0.325	bld	0.045	0.010	0.040
4	-	315	675	4570	30	2430	6785	bld	bld	bld	0.890	bld	0.010	bld	bld
5	8.4	-	-	-	-	-	-	bld	bld	bld	0.070	bld	0.055	bld	0.090
11	7.2	570	455	1960	36	1480	4055	bld	bld	bld	1.590	bld	0.420	bld	19.100
15	7.4	450	408	2000	28	1980	3476	bld	bld	bld	0.830	bld	0.150	bld	5.550
16	7.2	600	285	1770	27	2750	2524	bld	0.035	bld	5.690	bld	5.520	0.010	0.050
21	7.2	740	410	2300	22	1990	4639	bld	0.020	0.010	0.275	bld	1.370	0.015	0.040
24	7.0	-	-	-	-	-	-	bld	0.135	bld	10.800	0.310	3.150	bld	bld
25	6.9	780	475	4880	16	4250	6890	bld	bld	bld	0.740	bld	0.105	bld	bld
Decant	7.3	970	90	2150	105	2590	3250	bld	.008	bld	19.400	1.680	bld	-	bld
Toe Drain	7.3	900	135	2640	125	2680	4090	bld	bld	bld	14.100	bld	1.135	bld	bld

bld denotes below level of detection

Groundwater Quality Investigation - No.3 Shaft, Perilya North Mine, Broken Hill

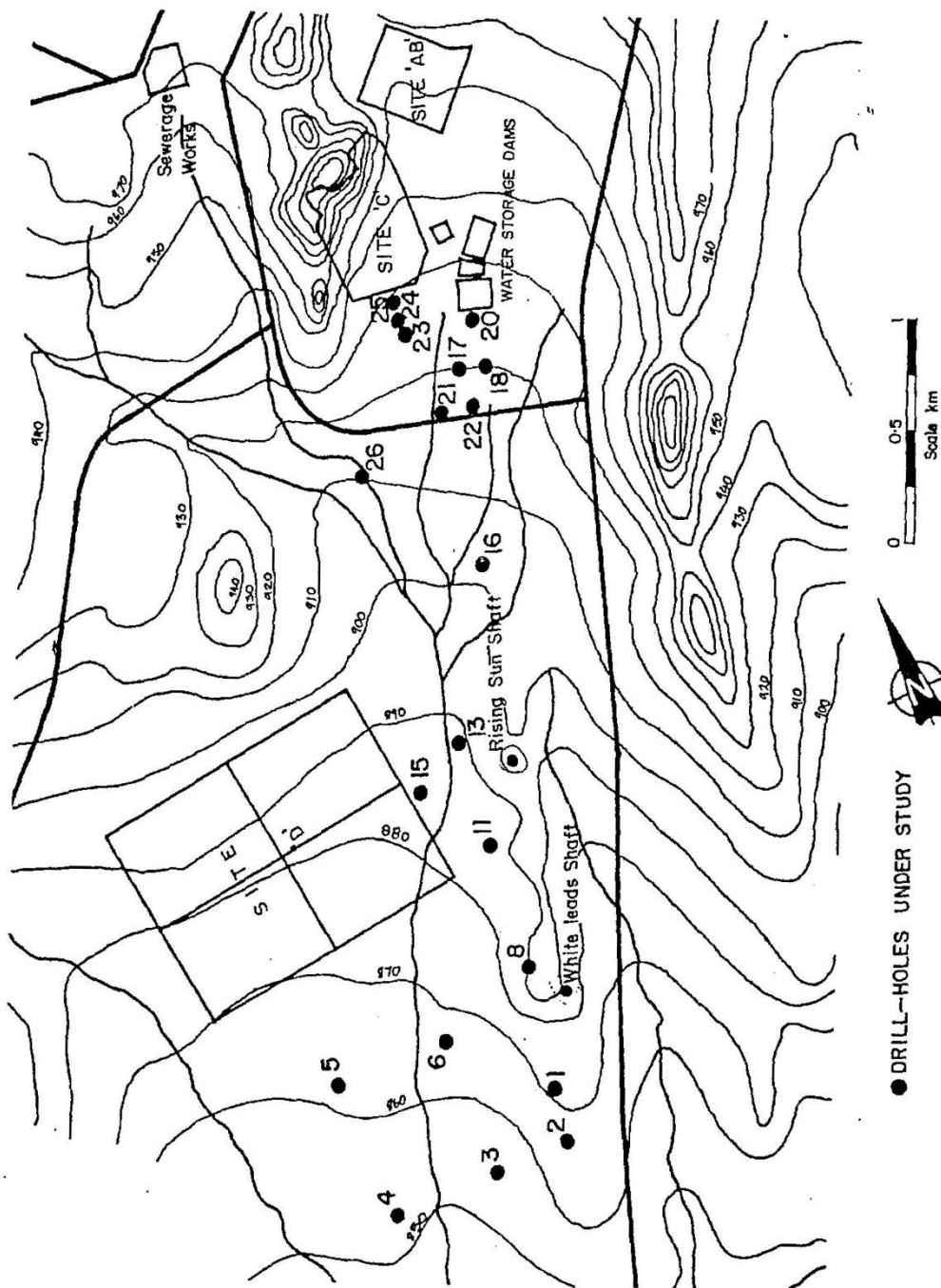


Figure B1
Southern Leases Drill-hole Locations

Report Ref: J1262.9R
Rev:0
Rev Date: 22-Nov-11
Author: LER

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APPENDIX C

Overview of the Hydrasleeve™ Discrete Interval Sampler

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APPENDIX C

OVERVIEW OF THE HYDRASLEEVE DECSRETE INTERVAL SAMPLER

The HydraSleeve™ (Figure 2) is a grab-type sampling device comprised of a long polyethylene bag with a reed valve at the top and a weight attached to the bottom. The sampler dimensions can be customized to meet project-specific sample volume requirements and well diameters.

To initiate the collection process, the closed sampler is lowered into the screened interval by a suspension line attached to a stainless steel weight. The sampler is allowed to sit undisturbed to allow for equilibration. After the prescribed time, the sampler is pulled upward at a minimum rate of 1 foot per minute. The upward motion causes the reed valve to open and water to enter the sleeve.

Earlier versions of the HydraSleeve™ were equipped with a check valve, which required that the device be moved up and down in the well to bring water into the bag. This practice disrupted the water column and increased turbidity in some wells. With the reed valve, the HydraSleeve™ induces only minimal agitation of the well water. The internal water pressure keeps the reed valve closed when the bag is filled so that mixing with water above the screened interval cannot occur.

Once withdrawn from the well, the sample should be squeezed out of the bag into appropriate containers through a tube inserted below the check valve. For sampling of LTM wells at regular frequency, the HydraSleeve™ can be left sealed in the screened well interval for indefinite periods between sampling events.

MacMillan, D. & D. E. Splichal 2005, *Review of Field Technologies for Long-Term Monitoring of Ordnance-Related Compounds in Groundwater*, Environmental Quality and Technology Program. US Army Corps of Engineers, Engineer Research and Development Centre, 2005, pp 12 – 14; ERDC/EL TR-05-14 (<http://el.erd.c.usace.army.mil/elpubs/pdf/trel05-14.pdf>)

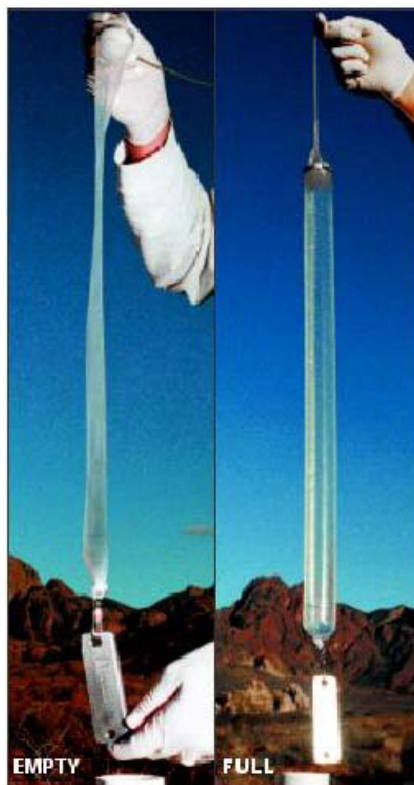


Figure 2. The HydraSleeve™. Photo used with permission. (<http://www.hydrasleeve.com/>)

This sampling technique has been demonstrated for many environmental contaminants of concern to the military, including volatile organics, explosives and redox sensitive elements. No significant differences in recoveries of volatile organic compounds and explosives were observed between samples collected with the HydraSleeve™ versus control samples (Parker and Clark 2002). There are many advantages to using the HydraSleeve™ over other sampling techniques, including its compatibility with deployment in a monitoring well for long periods of time prior to sample collection. Bio-fouling is not a factor since compounds do not diffuse into the bags.

The manufacturer reports 50 to 80% sampling cost savings can be obtained using this device. Since the bags can be reused in the same well, decontamination of sampling equipment is not necessary.

Parker, L. V. & C. H. Clark 2002, *Study of five discrete interval-type groundwater sampling devices*, ERDC/CRREL TR-02-12, US Army Engineer Research and Development Center, Hanover, NH

Further information can be found on the company's website <http://www.dsienv.com/Hydrasleeve.htm>



APPENDIX D

Chain-of-Custody and Sample Receipt Documentation

CMJA

ALS Sydney: 277-288 Woodpark Road, Smithfield, NSW 2164. Phone (02) 8784 8555; Facsimile (02) 8784 8500. Email Samples.Sydney@alsenviro.com

CMJA

CHAIN OF CUSTODY DOCUMENTATION				Australia Services Pty Ltd	
CLIENT: C.M. Jewell & Associates Pty Ltd		SAMPLER: Lesley Randall			
ADDRESS/OFFICE: P.O.Box 10, Wentworth Falls, Australia 2782		MOBILE: 0428 619 804			
PROJECT MANAGER (PM): Lesley Randall		PHONE: 47 59 3251			
PROJECT ID: 1262		EMAIL REPORT TO: lesley@cm-jewell.com.au			
SITE: North Mine, Broken Hill		P.O. NO.:			
RESULTS REQUIRED: Normal TAT		QUOTE NO.: SV1274/10			
FOR LABORATORY USE ONLY		COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:			
COOLER SEAL (circle appropriate)		All heavy metals (dissolved) field filtered			
Intact: Yes No		As, Cd, Cr (total), Cu, Pb, Mn, Ni, Fe, Hg, Ag			
SAMPLE TEMPERATURE		Heavy metal bottles are NOT preserved			
CHILLED: Yes No					
SAMPLE INFORMATION (note: S = Soil, W = Water)		CONTAINER INFORMATION			
ALS ID	SAMPLE ID	MATRIX	DATE	Time	Type / Code
1	WC: 750	Water	15/11/11	4:00pm	P, N, Z, SG
2	WC: 910	Water	15/11/11	4:15pm	P, N, Z, SG
3	WC: 1160	Water	15/11/11	4:20pm	P, N, Z, SG
Major Anions and Cations					
Heavy Metals					
Sulphide					
TDS and TSS					
Oil and Grease					
Notes: e.g. Highly contaminated samples e.g. "High PAHs expected" Extra Volume for QC or trace LORs etc.					
Environmental Division Sydney Work Order ES1125312					
Barcode					
Telephone: +61-2-8784 8555					
RELINQUISHED BY:			RECEIVED BY:		
Name: Lesley Randall			Name: David		
Of: C.M. Jewell & Associates			Of: AS		
Date: 16 Nov 2011			Date: 17/11		
Time: 10:00am			Time: 1900		
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SAMPLE RECEIPT NOTIFICATION (SRN) Comprehensive Report

Work Order	: ES1125312		
Client	: C M JEWELL & ASSOC PTY LTD	Laboratory	: Environmental Division Sydney
Contact	: MS LESLEY RANDALL	Contact	: Client Services
Address	: P O BOX 10 WENTWORTH FALLS NSW, AUSTRALIA 2782	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: lesley@cm-jewell.com.au	E-mail	: sydney@alsglobal.com
Telephone	: +61 02 4759 3251	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 4759 3257	Facsimile	: +61-2-8784 8500
Project	: J262	Page	: 1 of 3
Order number	: ----		
C-O-C number	: ----	Quote number	: ES2010CMJEWE0284 (SY/274/10)
Site	: NORTH MINE,BROKEN HILL		
Sampler	: LR	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 17-NOV-2011	Issue Date	: 18-NOV-2011 14:38
Client Requested Due Date	: 25-NOV-2011	Scheduled Reporting Date	: 25-NOV-2011

Delivery Details

Mode of Delivery	: Carrier	Temperature	: 4.6°C - Ice present
No. of coolers/boxes	: 1 HARD	No. of samples received	: 3
Security Seal	: Intact.	No. of samples analysed	: 3

General Comments

- This report contains the following information:
 - Sample Container(s)/Preservation Non-Compliances
 - Summary of Sample(s) and Requested Analysis
 - Proactive Holding Time Report
 - Requested Deliverables
- Samples received in appropriately pretreated and preserved containers.
- Breaches in recommended extraction / analysis holding times may occur. Please contact ALS for further information.
- Appropriately preserved bottle not supplied for CrVI and CrIII analysis, ALS will sub sample from natural bottle supplied
- Cr6+ analysis must be conducted within 24 hours after sampling.
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of work order.

Address 277-289 Woodpark Road Smithfield NSW Australia 2164 | PHONE +61-2-8784 8555 | Facsimile +61-2-8784 8500
Environmental Division Sydney ABN 84 009 936 029 Part of the ALS Group - A Campbell Brothers Limited Company

Environmental

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Issue Date : 18-NOV-2011 14:38
 Page : 2 of 3
 Work Order : ES1125312
 Client : C M JEWELL & ASSOC PTY LTD



Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- No sample container / preservation non-compliance exist.

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default to 15:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory for processing purposes and will be shown bracketed without a time component.

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EA015H Total Dissolved Solids - High Level	WATER - EA025H Suspended Solids (High Level)	WATER - EG020F Dissolved Metals by ICPMS	WATER - EG035F Dissolved Mercury by FIMS	WATER - EG049G-F Dissolved Trivalent Chromium by ICP & DA	WATER - EG050G-F Dissolved Hexavalent Chromium by Discrete Analyser	WATER - EK085M Sulfide as S 2-	WATER - EN055 - PG Ionic Balance by ED037P, ED041G, ED045G & ED093F
ES1125312-001	15-NOV-2011 16:00	WC: 780	✓	✓	✓	✓	✓	✓	✓	✓
ES1125312-002	15-NOV-2011 16:15	WC: 970	✓	✓	✓	✓	✓	✓	✓	✓
ES1125312-003	15-NOV-2011 16:30	WC: 1160	✓	✓	✓	✓	✓	✓	✓	✓

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EP020 Oil & Grease (O&G)	WATER - NT-01 Major Cations (Ca, Mg, Na, K)	WATER - NT-02 Major Anions (Chloride, Sulphate, Alkalinity)
ES1125312-001	15-NOV-2011 16:00	WC: 780	✓	✓	✓
ES1125312-002	15-NOV-2011 16:15	WC: 970	✓	✓	✓
ES1125312-003	15-NOV-2011 16:30	WC: 1160	✓	✓	✓

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER**

Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method		Due for extraction	Due for analysis	Samples Received		Instructions Received	
Client Sample ID(s)	Container			Date	Evaluation	Date	Evaluation
EG050G-F: Hexavalent Chromium by Discrete Analyser - Dissolved							
WC: 1160	Clear Plastic Bottle - Natural	----	16-NOV-2011	17-NOV-2011	✗	----	----
WC: 780	Clear Plastic Bottle - Natural	----	16-NOV-2011	17-NOV-2011	✗	----	----
WC: 970	Clear Plastic Bottle - Natural	----	16-NOV-2011	17-NOV-2011	✗	----	----

Issue Date : 18-NOV-2011 14:38
Page : 3 of 3
Work Order : ES1125312
Client : C M JEWELL & ASSOC PTY LTD



Requested Deliverables**MS LESLEY RANDALL**

- *AU Certificate of Analysis - NATA (COA)
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)
- A4 - AU Tax Invoice (INV)
- Chain of Custody (CoC) (COC)
- EDI Format - ENMRG (ENMRG)

Email	lesley@cm-jewell.com.au
Email	lesley@cm-jewell.com.au
Email	lesley@cm-jewell.com.au
Email	lesley@cm-jewell.com.au
Print	MS LESLEY RANDALL
Email	lesley@cm-jewell.com.au
Email	lesley@cm-jewell.com.au

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APPENDIX E

Laboratory Certificates

CMJA



CERTIFICATE OF ANALYSIS

Work Order	: ES1125312	Page	: 1 of 4
Amendment	: 1		
Client	: C M JEWELL & ASSOC PTY LTD	Laboratory	: Environmental Division Sydney
Contact	: MS LESLEY RANDALL	Contact	: Client Services
Address	: P O BOX 10 WENTWORTH FALLS NSW, AUSTRALIA 2782	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: lesley@cm-jewell.com.au	E-mail	: sydney@alsglobal.com
Telephone	: +61 02 4759 3251	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 4759 3257	Facsimile	: +61-2-8784 8500
Project	: J262	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: 10000000000000000000	Date Samples Received	: 17-NOV-2011
C-O-C number	: 10000000000000000000	Issue Date	: 30-NOV-2011
Sampler	: LR	No. of samples received	: 3
Site	: NORTH MINE, BROKEN HILL	No. of samples analysed	: 3
Quote number	: SY/274/10		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

WORLD RECOGNISED
ACCREDITATION

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Nanthini Coilparampil	Laboratory Manager - Inorganics	Sydney Inorganics
Sarah Millington	Senior Inorganic Chemist	Sydney Inorganics
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics



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Environmental Division Sydney ABN 84 009 936 029 Part of the ALS Group A Campbell Brothers Limited Company



Page : 2 of 4
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- EG050G-F: Spike failed for Cr6+ analysis on sample ID: WC: 780 due to matrix interference! Confirmed by re-analysis
- EP020: LCS recovery for Oil and Grease falls outside ALS dynamic control limits. However, it is within the acceptance criteria based on ALS DQO. No further action is required.
- This report has been amended and re-released to allow the reporting of additional analytical data- Zinc analysis on samples 1-3 as per client request.

CMJA



Page : 3 of 4
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Analytical Results

Sub-Matrix: WATER

Sub-Matrix: WATER	Client sample ID		WC: 780	WC: 970	WC: 1160	
	CAS Number	LOR				
Compound			ES1125312-001	ES1125312-002	ES1125312-003	
EA015: Total Dissolved Solids						
Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	6470	8200	8610
EA025: Suspended Solids						
Suspended Solids (SS)	----	5	mg/L	98	32	33
ED037P: Alkalinity by PC Titrator						
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	76	67	67
Total Alkalinity as CaCO3	----	1	mg/L	76	67	67
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA						
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	2140	2620	2560
ED045G: Chloride Discrete analyser						
Chloride	16887-00-6	1	mg/L	1660	2220	2780
ED093F: Dissolved Major Cations						
Calcium	7440-70-2	1	mg/L	518	682	728
Magnesium	7439-95-4	1	mg/L	168	214	238
Sodium	7440-23-5	1	mg/L	1390	1690	1870
Potassium	7440-09-7	1	mg/L	48	62	67
EG020F: Dissolved Metals by ICP-MS						
Arsenic	7440-38-2	0.001	mg/L	0.073	0.099	0.098
Cadmium	7440-43-9	0.0001	mg/L	0.0101	0.0092	0.0101
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.005	0.006	0.006
Lead	7439-92-1	0.001	mg/L	0.062	0.167	0.198
Manganese	7439-96-5	0.001	mg/L	107	112	112
Nickel	7440-02-0	0.001	mg/L	0.151	0.171	0.171
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	35.7	38.8	39.0
Iron	7439-89-6	0.05	mg/L	23.8	29.7	29.0
EG035F: Dissolved Mercury by FIMS						
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001
EG049F: Dissolved Trivalent Chromium						
Trivalent Chromium	16065-83-1	0.01	mg/L	<0.01	<0.01	<0.01
EG050F: Dissolved Hexavalent Chromium						
Hexavalent Chromium	18540-29-9	0.010	mg/L	<0.010	<0.010	<0.010
EK085M: Sulfide as S2-						



Page : 4 of 4
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Analytical Results

Sub-Matrix: WATER

Sub-Matrix: WATER			Client sample ID								
Client sampling date / time			WC: 780			WC: 970			WC: 1160		
CAS Number	LOR	Unit	15-NOV-2011 16:00	15-NOV-2011 16:15	15-NOV-2011 16:30	ES1125312-001	ES1125312-002	ES1125312-003			
Compound											
EK085M: Sulfide as S2- - Continued											
Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1			<0.1			
EN055: Ionic Balance											
Total Anions		0.01	meq/L	92.9	118			133			
Total Cations		0.01	meq/L	101	127			139			
Ionic Balance		0.01	%	4.36	3.36			2.17			
EP020: Oil and Grease (O&G)											
Oil & Grease		5	mg/L	<5	<5			<5			
Oil & Grease		5	mg/L	<5	<5			<5			

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APPENDIX F

Quality Control Reports

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QUALITY CONTROL REPORT

Work Order	: ES1125312	Page	: 1 of 7
Amendment	: 1		
Client	: C M JEWELL & ASSOC PTY LTD	Laboratory	: Environmental Division Sydney
Contact	: MS LESLEY RANDALL	Contact	: Client Services
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Project	: J262	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: NORTH MINE, BROKEN HILL	Date Samples Received	: 17-NOV-2011
C-O-C number	: ---	Issue Date	: 30-NOV-2011
Sampler	: LR	No. of samples received	: 3
Order number	: ---	No. of samples analysed	: 3
Quote number	: SY/274/10		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits



NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.



Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Nanithi Coliparampil	Laboratory Manager - Inorganics	Sydney Inorganics
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Page : 2 of 7
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
 CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
 LOR = Limit of reporting
 RPD = Relative Percentage Difference
 # = Indicates failed QC

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Page : 3 of 7
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: WATER		Method/Compound	CAS Number	LOR	Unit	Laboratory Duplicate (DUP) Report			
Laboratory sample ID	Client sample ID					Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
ES1125020-005	Anonymous	EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	632	620	1.9	0% - 20%
	ES1125032-002	EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	152	154	1.3	0% - 20%
ES1125016-003	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	120	116	3.4	0% - 20%
	ES1125066-008	EA025H: Suspended Solids (SS)	----	5	mg/L	170	177	4.0	0% - 20%
ES1125398-010	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	<5	<5	0.0	No Limit
	ES1125452-009	EA025H: Suspended Solids (SS)	----	5	mg/L	740	832	11.7	0% - 20%
ES1125295-015	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	129	126	2.2	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	129	126	2.2	0% - 20%
ES1125326-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	242	242	0.0	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	242	242	0.0	0% - 20%
ES1124914-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1250	1280	2.0	0% - 20%
	ES1124914-010	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1260	1270	1.0	0% - 20%
ES1125111-011	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	113	112	0.0	0% - 20%
	ES1125111-018	ED045G: Chloride	16887-00-6	1	mg/L	26	25	0.0	0% - 20%
ES1124914-001	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	142	143	0.0	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	80	79	0.0	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	194	191	1.9	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	7	7	0.0	No Limit
ES1125024-001	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	3	3	0.0	No Limit
		ED093F: Magnesium	7439-95-4	1	mg/L	2	2	0.0	No Limit
		ED093F: Sodium	7440-23-5	1	mg/L	57	57	0.0	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	2	2	0.0	No Limit
ES1125312-003	WC: 1160	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	0.0101	0.0102	0.0	0% - 20%
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.098	0.098	0.0	0% - 20%



Page : 4 of 7
 Work Order : ES1125312 Amendment 1
 Client : C.M. JEWELL & ASSOC PTY LTD
 Project : J262

Sub-Matrix: WATER		Laboratory Duplicate (DUP) Report							
Laboratory sample ID	Client sample ID	Method/ Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
ES1125312-003	WC: 1160	EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.006	0.006	0.0	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	0.198	0.196	1.4	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.171	0.172	0.0	0% - 20%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	39.0	38.8	0.5	0% - 20%
ES1125399-006	Anonymous	EG020A-F: Iron	7439-89-6	0.05	mg/L	29.0	29.4	1.2	0% - 20%
		EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0010	<0.0010	0.0	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.010	0.048	131	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	0.024	0.012	68.0	0% - 50%
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.083	0.092	10.4	0% - 20%
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	0.0	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.010	0.020	68.6	0% - 20%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.050	<0.050	0.0	No Limit
ES1125399-006	Anonymous	EG020A-F: Iron	7439-89-6	0.05	mg/L	3.31	2.91	12.8	0% - 20%
		EG020B-F: Silver	7440-22-4	0.001	mg/L	<0.010	<0.010	0.0	No Limit
ES1125312-001	WC: 780	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
		EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
ES1125312-001	WC: 780	EG050G-F: Hexavalent Chromium	18540-29-9	0.010	mg/L	<0.010	<0.010	0.0	No Limit
ES1125312-001	WC: 780	EK085: Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1	0.0	No Limit

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 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

Sub-Matrix: WATER	Method/Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
						Spike Concentration	Spike Recovery (%)	LCS	Recovery Limits (%)
EA015: Total Dissolved Solids (QCLot: 2052000)									
	EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	<5	293 mg/L	99.0	70	130
EA028: Suspended Solids (QCLot: 2051403)									
	EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	103	30	150
EA025: Suspended Solids (QCLot: 2051404)									
	EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	100	30	150
ED037P: Alkalinity by PC Titrator (QCLot: 2051987)									
	ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	200 mg/L	82.8	75	107
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 2052512)									
	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	90.8	77	121
ED045G: Chloride Discrete analyser (QCLot: 2052514)									
	ED045G: Chloride	16887-00-6	1	mg/L	<1	1000 mg/L	98.1	79	123
ED093F: Dissolved Major Cations (QCLot: 2052510)									
	ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	98.7	88	110
	ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	99.8	90	110
	ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	100	81	107
	ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	104	89	109
EG020F: Dissolved Metals by ICP-MS (QCLot: 2055620)									
	EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	93.4	88	110
	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	95.6	89	107
	EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	99.6	91	111
	EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	98.9	87	111
	EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	91.5	90	110
	EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	102	89	109
	EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	93.2	85	115
	EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	97.0	84	114
EG020F: Dissolved Metals by ICP-MS (QCLot: 2055622)									
	EG020B-F: Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 2060619)									
	EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	104	87	113
EG035F: Dissolved Mercury by FIMS (QCLot: 2055621)									
	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	87.5	86	116
EG050F: Dissolved Hexavalent Chromium (QCLot: 2050254)									
	G050G-F: Hexavalent Chromium	18540-29-9	0.01	mg/L	<0.010	0.50 mg/L	100	86	120



Page : 6 of 7
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Sub-Matrix: WATER				Method Blank (MB) Report		Laboratory Control Spike (LCS) Report		
Method: Compound	CAS Number	LOR	Unit	Result	Spike Concentration	Spike Recovery (%)	Recovery Limits (%)	
EK085M: Sulfide as S ₂ - (QCLot: 2053340)								
EK085: Sulfide as S ₂ -	18496-25-8	0.10	mg/L	<0.1	0.50 mg/L	102	70.2	121
EP020: Oil and Grease (O&G) (QCLot: 2054458)								
EP020: Oil & Grease	----	5	mg/L	<5	5000 mg/L	# 114	81.6	107

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Page : 7 of 7
 Work Order : ES1125312 Amendment 1
 Client : C M JEWELL & ASSOC PTY LTD
 Project : J262

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID				Matrix Spike (MS) Report				
Laboratory sample ID		Client sample ID	Method: Compound	CAS Number	Spike Concentration	Spike Recovery (%) MS	Recovery Limits (%)	
						MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 2052512)								
ES1124914-001		Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	# Not Determined	70	130
ED045G: Chloride Discrete analyser (QCLot: 2052514)								
ES1125111-011		Anonymous	ED045G: Chloride	16887-00-6	250 mg/L	111	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 2055620)								
ES1125395-003		Anonymous	EG020A-F: Arsenic	7440-38-2	0.2 mg/L	101	70	130
			EG020A-F: Cadmium	7440-43-9	0.05 mg/L	100	70	130
			EG020A-F: Chromium	7440-47-3	0.2 mg/L	92.0	70	130
			EG020A-F: Copper	7440-50-8	0.2 mg/L	98.4	70	130
			EG020A-F: Lead	7439-92-1	0.2 mg/L	96.8	70	130
			EG020A-F: Nickel	7440-02-0	0.2 mg/L	104	70	130
			EG020A-F: Zinc	7440-66-6	0.2 mg/L	110	70	130
EG035F: Dissolved Mercury by FIMS (QCLot: 2055621)								
ES1125312-002		WC: 970	EG035F: Mercury	7439-97-6	0.0100 mg/L	86.8	70	130
EG050F: Dissolved Hexavalent Chromium (QCLot: 2050254)								
ES1125312-001		WC: 780	EG050G-F: Hexavalent Chromium	18540-29-9	0.50 mg/L	# Not Determined	70	130
EK085M: Sulfide as S2- (QCLot: 2053340)								
ES1125312-001		WC: 780	EK085: Sulfide as S2-	18496-25-8	0.33 mg/L	118	70	130



INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: ES1125312	Page	: 1 of 8
Amendment	: 1		
Client	: C M JEWELL & ASSOC PTY LTD	Laboratory	: Environmental Division Sydney
Contact	: MS LESLEY RANDALL	Contact	: Client Services
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Telephone	: +61 02 4759 3251	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 4759 3257	Facsimile	: +61-2-8784 8500
Project	: J262	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: NORTH MINE, BROKEN HILL	Date Samples Received	: 17-NOV-2011
C-O-C number	: ----	Issue Date	: 30-NOV-2011
Sampler	: LR	No. of samples received	: 3
Order number	: ----	No. of samples analysed	: 3
Quote number	: SY274/10		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

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Page : 2 of 8
Work Order : ES1125312 Amendment 1
Client : CM JEWELL & ASSOC PTY LTD
Project : J262

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non-volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: WATER

Matrix: WATER		Evaluation: * = Holding time breach ; ✓ = Within holding time						
Method	Container / Client Sample D(s)	Sample Date	Extraction / Preparation		Analysis			
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA015: Total Dissolved Solids								
Clear Plastic Bottle - Natural (EA015H)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	----	----	21-NOV-2011	22-NOV-2011	✓
EA025: Suspended Solids								
Clear Plastic Bottle - Natural (EA025H)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	----	----	20-NOV-2011	22-NOV-2011	✓
ED037P: Alkalinity by PC Titrator								
Clear Plastic Bottle - Natural (ED037-P)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	29-NOV-2011	----	22-NOV-2011	29-NOV-2011	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Clear Plastic Bottle - Natural (ED041G)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	13-DEC-2011	----	22-NOV-2011	13-DEC-2011	✓
ED045G: Chloride Discrete analyser								
Clear Plastic Bottle - Natural (ED045G)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	13-DEC-2011	----	22-NOV-2011	13-DEC-2011	✓
ED093F: Dissolved Major Cations								
Clear Plastic Bottle - Natural (ED093F)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	22-NOV-2011	----	22-NOV-2011	22-NOV-2011	✓
EG020F: Dissolved Metals by ICP-MS								
Clear Plastic Bottle - Filtered; Lab-acidified (EG020A-F)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	13-MAY-2012	----	23-NOV-2011	13-MAY-2012	✓
EG020F: Dissolved Metals by ICP-MS								
Clear Plastic Bottle - Filtered; Lab-acidified (EG020B-F)	WC: 970, WC: 780, WC: 1160	15-NOV-2011	---	13-MAY-2012	----	23-NOV-2011	13-MAY-2012	✓

Evaluation: * = Holding time breach ; ✓ = Within holding time.



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Matrix: WATER

Evaluation: ✖ = Holding time breach ; ✔ = Within holding time.

Method	Container / Client Sample ID(s)	Sample Date	Extraction / Preparation		Analysis	
			Date extracted	Due for extraction	Evaluation	Date analysed
EG035F: Dissolved Mercury by FIMS						
Clear Plastic Bottle - Filtered; Lab-acidified (EG035F)	WC: 780, WC: 1160	15-NOV-2011	---	13-DEC-2011	----	23-NOV-2011
EG050F: Dissolved Hexavalent Chromium						
Clear Plastic Bottle - Natural (EG050G-F)	WC: 780, WC: 1160	15-NOV-2011	---	----	----	18-NOV-2011
EK085M: Sulfide as S2-						
Clear Plastic Bottle - Zinc Acetate/NaOH (EK085)	WC: 780, WC: 1160	15-NOV-2011	---	----	----	22-NOV-2011
EP020: Oil and Grease (O&G)						
Amber Glass Bottle - Sulfuric Acid (EP020)	WC: 780, WC: 1160	15-NOV-2011	---	----	----	22-NOV-2011

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Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(ware) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: * = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Method		Count		Rate (%)		Quality Control Specification	
Analytical Methods		QC	Regular	Actual	Expected	Evaluation			
Laboratory Duplicates (DUP)									
Alkalinity by PC Titrator	ED037-P	2	20	10.0	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Chloride by Discrete Analyser	ED045G	2	13	15.4	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Mercury by FIMS	EG035F	2	20	10.0	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	6	33.3	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	5	20.0	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Hexavalent Chromium by Discrete Analyser - Dissolved	EG050G-F	1	3	33.3	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Major Cations - Dissolved	ED093F	2	15	13.3	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	17	11.8	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfide as S2-	EK085	1	3	33.3	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Suspended Solids (High Level)	EA025H	4	35	11.4	9.5	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Total Dissolved Solids (High Level)	EA015H	2	20	10.0	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Laboratory Control Samples (LCS)									
Alkalinity by PC Titrator	ED037-P	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Chloride by Discrete Analyser	ED045G	2	13	15.4	10.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Mercury by FIMS	EG035F	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	26	7.7	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	5	20.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Hexavalent Chromium by Discrete Analyser - Dissolved	EG050G-F	1	3	33.3	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Major Cations - Dissolved	ED093F	1	15	6.7	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Oil and Grease	EP020	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	17	5.9	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfide as S2-	EK085	1	3	33.3	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Suspended Solids (High Level)	EA025H	2	35	5.7	4.8	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Total Dissolved Solids (High Level)	EA015H	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Method Blanks (MB)									
Chloride by Discrete Analyser	ED045G	1	13	7.7	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Mercury by FIMS	EG035F	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	26	7.7	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	5	20.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Hexavalent Chromium by Discrete Analyser - Dissolved	EG050G-F	1	3	33.3	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Major Cations - Dissolved	ED093F	1	15	6.7	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Oil and Grease	EP020	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	17	5.9	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Sulfide as S2-	EK085	1	3	33.3	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Suspended Solids (High Level)	EA025H	2	35	5.7	4.8	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Total Dissolved Solids (High Level)	EA015H	1	20	5.0	5.0	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement		
Matrix Spikes (MS)									
Chloride by Discrete Analyser	ED045G	1	13	7.7	5.0	✓	ALS QCS3 requirement		
Dissolved Mercury by FIMS	EG035F	1	20	5.0	5.0	✓	ALS QCS3 requirement		

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Matrix: **WATER**

Quality Control Sample Type

Analytical Methods	Method	Count		Rate (%)		Quality Control Specification	
		QC	Regular	Actual	Expected	Evaluation	
Matrix Spikes (MS) - Continued							
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	6	16.7	5.0	✓	ALS QCS3 requirement
Hexavalent Chromium by Discrete Analyser - Dissolved	EG050G-F	1	3	33.3	5.0	✓	ALS QCS3 requirement
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	17	5.9	5.0	✓	ALS QCS3 requirement
Sulfide as S2-	EK085	1	3	33.3	5.0	✓	ALS QCS3 requirement

Evaluation: ✖ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

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Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Total Dissolved Solids (High Level)	EA015H	WATER	APHA 21st ed., 2540C A gravimetric procedure that determines the amount of 'filterable' residue in an aqueous sample. A well-mixed sample is filtered through a glass fibre filter (1.2um). The filtrate is evaporated to dryness and dried to constant weight at 180+/-5C. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Suspended Solids (High Level)	EA025H	WATER	APHA 21st ed., 2540D A gravimetric procedure employed to determine the amount of 'non-filterable' residue in a aqueous sample. The prescribed GFC (1.2um) filter is rinsed with deionised water, oven dried and weighed prior to analysis. A well-mixed sample is filtered through a glass fibre filter (1.2um). The residue on the filter paper is dried at 104+/-2C. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Alkalinity by PC Titrator	ED037-P	WATER	APHA 21st ed., 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrator) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	APHA 21st ed., 4500-SO4 Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Chloride by Discrete Analyser	ED045G	WATER	APHA 21st ed., 4500 Cl - G The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride in the presence of ferric ions the liberated thiocyanate forms highly-coloured ferric thiocyanate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	Major Cations is determined based on APHA 21st ed., 3120; USEPA SW 846 - 6010 The ICPAES technique ionises the 0.45um filtered sample atoms emitting a characteristic spectrum. This spectrum is then compared against matrix matched standards for quantification. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	Sodium Absorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite B	EG020B-F	WATER	Total Hardness is calculated based on APHA 21st ed., 2340 B. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
			(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): Samples are 0.45 um filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
			(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): Samples are 0.45 um filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.



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Analytical Methods	Method	Matrix	Method Descriptions
Dissolved Mercury by FIMS	EG035F	WATER	AS 3550, APHA 21st ed., 3112 Hg - B (Flow-injection (SnCl ₂)(Cold Vapour generation) AAS) Samples are 0.45 um filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl ₂ which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Trivalent Chromium - Dissolved	EG049G-F	WATER	APHA 21st ed., 3500 Cr-B & 3120/3125 Trivalent Chromium is the difference between total dissolved and dissolved hexavalent chromium.
Hexavalent Chromium by Discrete Analyser - Dissolved	EG050G-F	WATER	APHA 21st ed., 3500 Cr-A & B. Samples are 0.45 um filtered prior to analysis. Hexavalent chromium is determined directly on water sample by Discrete Analyser as received by pH adjustment and colour development using diphenylcarbazide. Each run of samples is measured against a five-point calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Sulfide as S ₂ -	EK085	WATER	APHA 21st ed., 4500-S ₂ -D Sulfide species present in water samples are immediately precipitated when collected in pretreated caustic/zinc acetate preserved sample containers. After the supernatant is discarded, the resultant precipitate is then coloured using methylene blue indicator and measured using UV-VIS detection at 664nm. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Ionic Balance by PCT DA and ICPAES	EN055 - PG	WATER	APHA 21st Ed. 1030F. The Ionic Balance is calculated based on the major Anions and Cations. The major anions include Alkalinity, Chloride and Sulfate which determined by PCT and DA. The Cations are determined by ICPAES. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Oil and Grease	EP020	WATER	APHA 21st ed., 5520 B Oil & grease is a gravimetric procedure to determine the amount of oil & grease residue in an aqueous sample. The sample is serially extracted three times n-hexane. The resultant extracts are combined, dehydrated and concentrated prior to gravimetric determination. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals	EN25	WATER	USEPA SW846-3005 Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Lab Acidification of Dissolved Metals	EN80F	WATER	US EPA Method 200.8

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Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QW/EN38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: WATER

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Laboratory Control Spike (LCS) Recoveries							
EP020: Oil and Grease (O&G)	2430568-002	----	Oil & Grease	----	114 %	81.6-107%	Recovery greater than upper control limit
Matrix Spike (MS) Recoveries							
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	ES1124914-001	Anonymous	Sulfate as SO4 - Turbidimetric	14808-79-8	Not Determined	----	MS recovery not determined, background level greater than or equal to 4x spike level.
EG050F: Dissolved Hexavalent Chromium	ES1125312-001	WC: 780	Hexavalent Chromium	18540-29-9	Not Determined	----	Matrix spike recovery not determined due to sample matrix interference.

- For all matrices, no Method Blank value outliers occur.
- For all matrices, no Duplicate outliers occur.
- For all regular sample matrices, no surrogate recovery outliers occur.

Regular Sample Surrogates

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: WATER

Method	Container / Client Sample ID(s)	Date extracted	Extraction / Preparation Due for extraction	Days overdue	Date analysed	Analysis Due for analysis	Days overdue
EG050F: Dissolved Hexavalent Chromium							
Clear Plastic Bottle - Natural	WC: 970, WC: 780, WC: 1160	-----	-----	-----	18-NOV-2011	16-NOV-2011	2

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- No Quality Control Sample Frequency Outliers exist.



APPENDIX G

Water Quality Guidelines

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APPENDIX G1
Australian Drinking Water Guidelines
(2011)

10.3.6 PERFORMANCE REPORTING

Performance assessment, based on the long-term review of monitoring data, should be reported internally to relevant staff and departments, as well as to senior management.

Performance reporting on water supply systems is also an important issue for health and regulatory authorities, and for consumers. Providing assurance that performance is reviewed regularly and that improvements are made in response to identified problems contributes to confidence in the water supplied and the water supply organisation. External reporting ensures that system management and drinking water quality performance remains open and transparent. External reporting may be done through an annual report, the contents of which may be determined by a regulatory agency.

10.3.7 SUMMARY OF GUIDELINE VALUES FOR MICROBIAL, CHEMICAL AND PHYSICAL AND CHARACTERISTICS

Tables 10.4 and 10.5 summarise of the guideline values for microbial, chemical and physical and characteristics, to provide a ready reference when monitoring results are being evaluated. More detailed information on each characteristic can be found in the relevant fact sheet.

Table 10.4 Performance measure for *Escherichia coli* within the distribution system

- *Escherichia coli* (*E. coli*) should not be detected in a minimum 100 mL sample of drinking water.
- If detected, immediate corrective action must be taken

Table 10.5 Guideline values for physical and chemical characteristics

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Acephate	0.008		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Acrylamide	0.0002		Minor impurity of polyacrylamide, used sometimes as a flocculant aid.
Aldicarb	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Aldrin & Dieldrin	0.0003 (combined)		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Aluminium (acid-soluble)	c	0.2	Guideline value based on post-flocculation problems; < 0.1 mg/L desirable. Lower levels needed for renal dialysis. No health-based guideline value can be established currently.
Ametryn	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Amitraz	0.009		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Amitrole	0.009		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Ammonia (as NH ₃)	c	0.5	Presence may indicate sewage contamination and/or microbial activity. High levels may corrode copper pipes and fittings.
Antimony	0.003		Exposure may rise with increasing use of antimony–tin solder.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Arsenic	0.01		From natural sources and mining/industrial/agricultural wastes.
Asbestos	c		From dissolution of minerals/industrial waste, deterioration of asbestos-cement pipes in distribution systems. No evidence of cancer when ingested (unlike inhaled asbestos).
Asulam	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Atrazine	0.02		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Azinphos-methyl	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Barium	2		Primarily from natural sources.
Benomyl	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Bentazone	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Benzene	0.001		Could occur in drinking water from atmospheric deposition (motor vehicle emissions) and chemical plant effluent. Human carcinogen.
Beryllium	0.06		From weathering of rocks, atmospheric deposition (burning of fossil fuels) discharges.
Bioresmethrin	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Boron	4		From natural leaching of minerals and contamination. <1 mg/L in uncontaminated sources; higher levels may be associated with seawater intrusion.
Bromacil	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Bromate	0.02		Possible by-product of disinfection using ozone, otherwise unlikely to be found in drinking water.
Bromophos-ethyl	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Bromoxynil	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Cadmium	0.002		Indicates industrial or agricultural contamination; from impurities in galvanised (zinc) fittings, solders and brasses.
Captan	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Carbaryl	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Carbendazim	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Carfentrazone-ethyl	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Carbofuran	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Carbon tetrachloride	0.003		Sometimes occurs as impurity in chlorine used for disinfection (it is not a disinfection by-product).
Carbophenothion	0.0005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Carboxin	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chloramine — see monochloramine			
Chlorantraniliprole	6		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chlorate	c e		By-product of chlorination. Insufficient data to set a health-related guideline value.
Chlordane	0.002		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chlorfenvinphos	0.002		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chloride	c	250	From natural mineral salts, effluent contamination. High concentrations more common in groundwater and certain catchments.
Chlorinated furanones (MX)	c e		By-product of chlorination. Insufficient data to set a health-related guideline value.
Chlorine	5 (4.1 for chloram- inated systems)	0.6	Widely used to disinfect water, and this can produce (free) chlorinated organic by-products. Odour threshold generally 0.6 mg/L, but 0.2 mg/L for a few people. In some supplies it may be necessary to exceed the aesthetic guideline in order to maintain an effective disinfectant residual throughout the system.
Chlorine dioxide	c	0.4	Oxidising agent and disinfectant in water treatment.
Chlorite	0.8		By-product of chlorine dioxide disinfection. Action to reduce chlorite is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than chlorite.
Chloroacetic acids chloroacetic acid dichloroacetic acid trichloroacetic acid	e 0.15 0.1 0.1		By-product of chlorination. Action to reduce chloroacetic acids is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than chloroacetic acids.
Chlorobenzene	0.3	0.01	Could occur in drinking water from spills or discharges. Taste/odour threshold (0.01 mg/L) is well below health level.
Chloroketones 1,1-dichloropropanone 1,3-dichloropropanone 1,1,1-trichloropropanone 1,1,3-trichloropropanone	e c c c c		By-product of chlorination.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Chlorophenols	e		By-product of chlorination of water containing phenol or related chemicals.
2-chlorophenol	0.3	0.0001	
2,4-dichlorophenol	0.2	0.0003	Action to reduce chlorophenols is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than chlorophenols.
2,4,6-trichlorophenol	0.02	0.002	
Chloropicrin	c		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns. Data are inadequate to set a health-based guideline.
Chlorothalonil	0.05		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chloroxuron	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chlorpyrifos	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chlorsulfuron	0.2		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Chromium (as Cr(VI))	0.05		From industrial/agricultural contamination of raw water or corrosion of materials in distribution system/plumbing. If guideline value exceeded, analyse for hexavalent chromium.
Clopyralid	2		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Colour (true)		15 HU	An important aesthetic characteristic for customer acceptance. Treatment processes can be optimised to remove colour.
Copper	2	1	From corrosion of pipes/fittings by salt, low pH water. Taste threshold 3 mg/L. High concentrations colour water blue/green. >1 mg/L may stain fittings. >2 mg/L can cause ill effects in some people.
Cyanide	0.08		From industrial waste and some plants and bacteria.
Cyanogen chloride (as cyanide)	0.08		By-product of chloramination. Action to reduce cyanogen chloride is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than cyanogen chloride.
Cyfluthrin, Beta-cyfluthrin	0.05		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Cypermethrin isomers	0.2		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Cyprodinil	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
2,4-D [(2,4-Dichlorophenoxy) acetic acid]	0.03		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
DDT	0.009		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Deltamethrin	0.04		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Diazinon	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dicamba	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dichlobenil	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dichlorobenzenes 1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene	1.5 c 0.04	0.001 0.02 0.0003	Could occur in drinking water from spills, discharges, atmospheric deposition, leaching from contaminated soils. Health levels are well above offensive taste/odour thresholds.
Dichloroethanes 1,1-dichloroethane 1,2-dichloroethane	c 0.003		Could occur in drinking water from industrial effluents, spills, discharges.
Dichloroethenes 1,1-dichloroethene 1,2-dichloroethene	0.03 0.06		Rarely found in drinking water; found occasionally in groundwater from wells heavily contaminated by solvents.
Dichloromethane (methylene chloride)	0.004		Widely used solvent, commonly found in ground and surface waters overseas. Volatilises from surface waters and biodegrades in the atmosphere.
1,3-Dichloropropene	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dichloroprop / Dichloroprop-P	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dichlorvos	0.005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Disofop-methyl	0.005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dicofol	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dieldrin see Aldrin			
Difenzoquat	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Disflubenzuron	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dimethoate	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Diphenamid	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Diquat	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Dissolved oxygen	Not necessary	>85%	Low concentrations allow growth of nuisance microorganisms (iron/ manganese/sulfate/nitrate-reducing bacteria), causing taste and odour problems, staining, corrosion. Low oxygen concentrations are normal in groundwater supplies and the guideline value may not be achievable.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Disulfoton	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Diuron	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
2,2-DPA	0.5		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
EDB	0.001		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Endosulfan	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Endothal	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Epichlorohydrin	0.0005d		Used in manufacture of some resins used in water treatment.
EPTC	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Esfenvalerate	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Ethion	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Ethoprophos	0.001		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Ethylbenzene	0.3	0.003	Natural component of petrol and petroleum products.
Ethylenediamine tetraacetic acid (EDTA)	0.25		Metal-complexing agent widely used in industry and agriculture, and as a drug in chelation therapy.
Etridiazole	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenamiphos	0.0005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenarimol	0.04		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenchlorphos	c		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenitrothion	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenoprop	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fensulfothion	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenthion	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fenvalerate	0.06		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Fipronil	0.0007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Flamprop-methyl	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fluometuron	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fluoride	1.5		Occurs naturally in some water from fluoride-containing rocks. Often added at up to 1 mg/L to protect against dental caries. >1.5 mg/L can cause dental fluorosis. >4 mg/L can cause skeletal fluorosis.
Fluproponate	0.009		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Formaldehyde	0.5		By-product of ozonation.
Formothion	0.05		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Fosamine	0.03		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Glyphosate	1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Haloacetonitriles dichloroacetonitrile trichloroacetonitrile dibromoacetonitrile bromochloroacetonitrile	e c c c c		By-product of chlorination.
Haloxyfop	0.001		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Hardness (as CaCO ₃)	Not necessary	200	Caused by calcium and magnesium salts. Hard water is difficult to lather. <60 mg/L CaCO ₃ – soft but possibly corrosive. 60-200 mg/L CaCO ₃ – good quality. 200-500 mg/L CaCO ₃ – increasing scaling problems. >500 mg/L CaCO ₃ – severe scaling.
Heptachlor	0.0003		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Hexachlorobutadiene	0.0007		Industrial solvent.
Hexaflurate	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Hexazinone	0.4		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Hydrogen sulfide	c	0.05	Formed in water by sulfate-reducing microorganisms or hydrolysis of soluble sulfide under anoxic conditions. Obnoxious 'rotten egg' odour, threshold 0.05 mg/L.
Imazapyr	9		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Iodide	0.5		From mineral and salt deposits.
Iodine	c		Can be used as an emergency water disinfectant. Taste threshold 0.15 mg/L.
Iprodione	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Iron	c	0.3	Occurs naturally in water, usually at <1 mg/L, but up to 100 mg/L in oxygen-depleted groundwater. Taste threshold 0.3 mg/L. High concentrations stain laundry and fittings. Iron bacteria cause blockages, taste/odour, corrosion.
Lead	0.01		Occurs in water via dissolution from natural sources or household plumbing containing lead (e.g. pipes, solder).
Lindane	0.01		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Maldison (Malathion)	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Mancozeb	for ETU: 0.009		Mancozeb degrades in the environment to ethylene thiourea (ETU), hence the health-based guideline is based on the toxicity of ETU. Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Manganese	0.5	0.1	Occurs naturally in water; low in surface water; higher in oxygen-depleted water (e.g. groundwater at bottom of deep storages). >0.1 mg/L causes taste, staining. <0.05 mg/L desirable.
MCPA	0.04		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Mercury	0.001		From industrial emissions/spills. Very low concentrations occur naturally. Organic forms most toxic, but these are associated with biota, not water.
Metaldehyde	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Metham	for MITC: 0.001		Metham degrades to methylisothiocyanate (MITC) in the environment, hence the health-based guideline is based on the toxicity of MITC. Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Methidathion	0.006		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Methiocarb	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Methomyl	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Methoxychlor	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Methyl bromide	0.001		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Metiram	for ETU: 0.009		Metiram degrades in the environment to ethylene thiourea (ETU), hence the health-based guideline is based on the toxicity of ETU. Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Metolachlor/s- Metolachlor	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Metribuzin	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns
Metsulfuron-methyl	0.04		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Mevinphos	0.005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Microcystins	1.3 µg/L		Hepatotoxic peptide produced by a range of cyanobacteria, expressed as microcystin-LR toxicity equivalents.
Molinate	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Molybdenum	0.05		Concentrations usually <0.01 mg/L; higher concentrations from mining, agriculture, or fly-ash deposits from coal-fuelled power stations.
Monochloramine	3		Used as water disinfectant. Odour threshold 0.5 mg/L.
Monocrotophos	0.002		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Naphthalophos	c		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns. No value set, as the health concerns have not been fully evaluated.
Napropamide	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Nicarbazin	1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Nickel	0.02		Concentrations usually very low; but up to 0.5 mg/L reported after prolonged contact of water with nickel-plated fittings.
Nitralin	0.5		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Nitrate (as nitrate)	50		Occurs naturally. Increasing in some waters (particularly groundwater) from intensive farming and sewage effluent. Guideline value will protect bottle-fed infants under 3 months from methaemoglobinaemia. Adults and children over 3 months can safely drink water with up to 100 mg/L nitrate.
Nitritotriacetic acid	0.2		Chelating agent in laundry detergents (replacing phosphate). May enter water through sewage contamination.
Nitrite (as nitrite)	3		Rapidly oxidised to nitrate (see above).

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
N-Nitrosodimethylamine (NDMA)	0.001 mg/L (100 ng/L)		By-product of chloramination and to a lesser extent chlorination. Action to reduce N-Nitrosodimethylamine is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than N-Nitrosodimethylamine
Norflurazon	0.05		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Omethoate	0.001		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Organotins dialkyltins tributyltin oxide	c 0.001		Stabilisers in plastics. May leach from new polyvinyl chloride (PVC) pipes for a short time. Tributyltins are biocides used as antifouling agents on boats and in boiler waters.
Oryzalin	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Oxamyl	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns (for further information, see Information Sheet 1.6).
Ozone			As ozone used for disinfection leaves no residual, no guideline value or fact sheet has been provided.
Paraquat	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Parathion	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Parathion-methyl	0.0007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pebulate	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pendimethalin	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pentachlorophenol	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Permethrin	0.2		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
pH	c	pH 6.5–8.5	While extreme pH values (<4 and >11) may adversely affect health, there are insufficient data to set a health guideline value. <6.5 may be corrosive. >8 progressively decreases efficiency of chlorination. >8.5 may cause scale and taste problems. New concrete tanks and cement-mortar lined pipes can significantly increase pH and a value up to 9.2 may be tolerated provided monitoring indicates no deterioration in microbial quality.
Picloram	0.3		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Piperonyl butoxide	0.6		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Pirimicarb	0.007		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Pirimiphos-ethyl	0.0005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pirimiphos methyl	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Plasticisers di(2-ethylhexyl) phthalate di(2-ethylhexyl) adipate	0.01 c		Used in all flexible PVC products, and may leach from these over a long time. Could also occur in drinking water from spills.
Polihexanide	0.7		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Polycyclic aromatic hydrocarbons (PAHs) Benzo-(a)-pyrene	0.00001 (10 ng/L)		Widespread. Contamination can occur through atmospheric deposition, or leaching from bituminous linings in distribution systems.
Profenofos	0.0003		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Promecarb	c		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propachlor	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propanil	0.7		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propargite	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propazine	0.05		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propiconazole	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Propyzamide	0.07		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pyrasulfotole	0.04		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pyrazophos	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Pyroxsulam	4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Quintozene	0.03		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Selenium	0.01		Generally very low concentrations in natural water..
Silica		80	An important characteristic for both aesthetics and treatment processes. Can form films on glass and can also affect reverse osmosis.
Silver	0.1		Concentrations generally very low. Silver and silver salts occasionally used for disinfection.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Simazine	0.02		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns.
Sodium	Not necessary	180	Natural component of water. Guideline value is taste threshold.
Spirotetramat	0.2		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns
Styrene (vinylbenzene)	0.03	0.004	Could occur in drinking water from industrial contamination.
Sulfate	500	250	Natural component of water, and may be added via treatment chemicals. Guideline value is taste threshold. >500 mg/L can have purgative effects.
Sulprofos	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns
2,4,5-T	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns
Taste and odour	Not necessary	Not offensive to most people	May indicate undesirable contaminants, but usually indicate problems such as algal or biofilm growths.
Temephos	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Temperature	Not necessary	No value set	Generally impractical to control; rapid changes can bring complaints.
Terbacil	0.2		Pesticide, has occasionally been reported in Australian drinking waters, but unlikely to be found at levels that may cause health concerns
Terbufos	0.0009		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Terbutylazine	0.01		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Terbutryn	0.4		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Tetrachloroethene	0.05		Dry-cleaning solvent and metal degreaser. Could occur in drinking water from contamination or spills.
Tetrachlorvinphos	0.1		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Thiobencarb	0.04		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Thiometon	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Thiophanate	0.005		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Thiram	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Tin	Not necessary		Concentrations in water very low; one of the least toxic metals.

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Toltrazuril	0.004		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Toluene	0.8	0.025	Occurs naturally in petrol and natural gas, forest-fire emissions. Could occur in drinking water from atmospheric deposition, industrial contamination, leaching from protective coatings in storage tanks.
Total dissolved solids	Not necessary	600	Based on taste: <600 mg/L is regarded as good quality drinking water. 600-900 mg/L is regarded as fair quality 900-1200 mg/L is regarded as poor quality >1200 mg/L is regarded as unacceptable.
Triadimefon	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Trichlorfon	0.007		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Trichloroacetaldehyde (chloral hydrate)	0.02 e		By-product of chlorination. Action to reduce trichloroacetaldehyde is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than trichloroacetaldehyde.
Trichlorobenzenes (total)	0.03	0.005	Industrial chemical.
1,1,1-Trichloroethane	c		Could occur in drinking water from contamination/spills.
Trichloroethylene	c		Industrial solvent, cleaning fluid, metal degreaser. Could occur in drinking water from direct contamination or via atmospheric contamination of rainwater.
Triclopyr	0.02		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Trifluralin	0.09		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Trihalomethanes (THMs) (Total)	0.25 e		By-product of chlorination and chloramination. Action to reduce trihalomethanes is encouraged, but must not compromise disinfection, as non-disinfected water poses significantly greater risk than trihalomethanes.
Turbidity	c	5 NTU	5 NTU is just noticeable in a glass. <0.2 NTU is the target for effective filtration of Cryptosporidium and Giardia. <1 NTU is the target for effective disinfection.
Uranium	0.017		Occurs naturally, or from release from mill tailings, combustion of coal and phosphate fertilizers.
Vernolate	0.04		Pesticide, unlikely to be found in drinking water at levels that may cause health concerns.
Vinyl chloride	0.0003		From chemical spills. Used in making PVC pipes. Human carcinogen.
Xylene	0.6	0.02	Could occur in drinking water as a pollutant, or from solvent used for bonding plastic fittings.

Chapter 10 Monitoring for Specific Characteristics in Drinking Water

Characteristic	Guideline values (mg/L unless otherwise specified)		Comments
	Health	Aesthetic	
Zinc	c	3	Usually from corrosion of galvanised pipes/fittings and brasses. Natural concentrations generally <0.01 mg/L. Taste problems >3 mg/L.

HU = Hazen units; NTU = nephelometric turbidity units; THMs = trihalomethanes.

- a Aesthetic values are not listed if the compound does not cause aesthetic problems, or if the value determined from health considerations is the same or lower.
- b If present at all in Australian drinking waters, concentrations of all organic compounds other than disinfection byproducts are likely to be very low relative to the guideline value.
- c Insufficient data to set a guideline value based on health considerations.
- d The guideline value is below the limit of quantitation. Improved analytical procedures are required for this compound.
- e The concentration of all chlorination byproducts can be minimised by removing naturally occurring organic matter from the source water; reducing the amount of chlorine added, or using an alternative disinfectant (which may produce other byproducts). Action to reduce trihalomethanes and other byproducts is encouraged, but must not compromise disinfection.

Note: All values are as 'total' unless otherwise stated.

Note: Routine monitoring for these compounds is not required unless there is potential for contamination of water supplies (e.g. accidental spillage).

Table 10.6 Guideline values radiological quality of drinking water

Guideline value

The total estimated dose per year from all radionuclides in drinking water, excluding the dose from potassium-40, should not exceed 1.0 mSv.

If this guideline value is exceeded, the water provider, in conjunction with the relevant health authority, should evaluate possible remedial actions on a cost-benefit basis to assess what action can be justified to reduce the annual exposure.

Screening of water supplies

Compliance with the guideline for radiological quality of drinking water should be assessed, initially, by screening for gross alpha and gross beta activity concentrations. The recommended screening level for gross alpha activity is 0.5 Bq/L. The recommended screening level for gross beta activity is 0.5 Bq/L after subtraction of the contribution from potassium-40.

If either of these activity concentrations is exceeded, specific radionuclides should be identified and their activity concentrations determined. The concentrations of both radium-226 and radium-228 should always be determined, as these are the most significant naturally occurring radionuclides in Australian water supplies. Other radionuclides should be identified if necessary to ensure all gross alpha and beta activity is accounted for, after taking into account the counting and other analytical uncertainties involved in their determination.

10.4 Reference

Mosse P, Murray B (2008). *Practical Guide to the Operation and Optimisation of Media Filters*. Water Industry Operators Association, Shepparton.



APPENDIX G2

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)

CMJA

3.4.2 How guidelines are developed for toxicants

Table 3.4.1 Trigger values for toxicants at alternative levels of protection. Values in grey shading are the trigger values applying to typical *slightly–moderately disturbed systems*; see table 3.4.2 and Section 3.4.2.4 for guidance on applying these levels to different ecosystem conditions.

Chemical		Trigger values for freshwater (µg/L ⁻¹)				Trigger values for marine water (µg/L ⁻¹)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
METALS & METALLOIDS									
Aluminium	pH >6.5	27	55	80	150	ID	ID	ID	ID
Aluminium	pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Antimony		ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)		1	24	94 ^C	360 ^C	ID	ID	ID	ID
Arsenic (AsV)		0.8	13	42	140 ^C	ID	ID	ID	ID
Beryllium		ID	ID	ID	ID	ID	ID	ID	ID
Bismuth		ID	ID	ID	ID	ID	ID	ID	ID
Boron		90	370 ^C	680 ^C	1300 ^C	ID	ID	ID	ID
Cadmium	H	0.06	0.2	0.4	0.8 ^C	0.7 ^B	5.5 ^{B,C}	14 ^{B,C}	36 ^{B,A}
Chromium (Cr III)	H	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (CrVI)		0.01	1.0 ^C	6 ^A	40 ^A	0.14	4.4	20 ^C	85 ^C
Cobalt		ID	ID	ID	ID	0.005	1	14	150 ^C
Copper	H	1.0	1.4	1.8 ^C	2.5 ^C	0.3	1.3	3 ^C	8 ^A
Gallium		ID	ID	ID	ID	ID	ID	ID	ID
Iron		ID	ID	ID	ID	ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID	ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 ^C	2.2	4.4	6.6 ^C	12 ^C
Manganese		1200	1900 ^C	2500 ^C	3600 ^C	ID	ID	ID	ID
Mercury (inorganic)	B	0.06	0.6	1.9 ^C	5.4 ^A	0.1	0.4 ^C	0.7 ^C	1.4 ^C
Mercury (methyl)		ID	ID	ID	ID	ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID	ID	ID	ID	ID
Nickel	H	8	11	13	17 ^C	7	70 ^C	200 ^A	560 ^A
Selenium (Total)	B	5	11	18	34	ID	ID	ID	ID
Selenium (SeIV)	B	ID	ID	ID	ID	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 ^C	0.8	1.4	1.8	2.6 ^C
Thallium		ID	ID	ID	ID	ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID	0.0004	0.006 ^C	0.02 ^C	0.05 ^C
Uranium		ID	ID	ID	ID	ID	ID	ID	ID
Vanadium		ID	ID	ID	ID	50	100	160	280
Zinc	H	2.4	8.0 ^C	15 ^C	31 ^C	7	15 ^C	23 ^C	43 ^C
NON-METALLIC INORGANICS									
Ammonia	D	320	900 ^C	1430 ^C	2300 ^A	500	910	1200	1700
Chlorine	E	0.4	3	6 ^A	13 ^A	ID	ID	ID	ID
Cyanide	F	4	7	11	18	2	4	7	14
Nitrate	J	17	700	3400 ^C	17000 ^A	ID	ID	ID	ID
Hydrogen sulfide	G	0.5	1.0	1.5	2.6	ID	ID	ID	ID
ORGANIC ALCOHOLS									
Ethanol		400	1400	2400 ^C	4000 ^C	ID	ID	ID	ID
Ethylene glycol		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl alcohol		ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKANES									
Chloromethanes									
Dichloromethane		ID	ID	ID	ID	ID	ID	ID	ID
Chloroform		ID	ID	ID	ID	ID	ID	ID	ID
Carbon tetrachloride		ID	ID	ID	ID	ID	ID	ID	ID
Chloroethanes									
1,2-dichloroethane		ID	ID	ID	ID	ID	ID	ID	ID
1,1,1-trichloroethane		ID	ID	ID	ID	ID	ID	ID	ID

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Chemical	Trigger values for freshwater ($\mu\text{g/L}^{-1}$)				Trigger values for marine water ($\mu\text{g/L}^{-1}$)			
	Level of protection (% species)				Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
1,1,2-trichloroethane	5400	6500	7300	8400	140	1900	5800 ^C	18000 ^C
1,1,2,2-tetrachloroethane	ID	ID	ID	ID	ID	ID	ID	ID
Pentachloroethane	ID	ID	ID	ID	ID	ID	ID	ID
Hexachloroethane B	290	360	420	500	ID	ID	ID	ID
Chloropropanes								
1,1-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropane	ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKENES								
Chloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1-dichloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1,2-trichloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
1,1,2,2-tetrachloroethylene	ID	ID	ID	ID	ID	ID	ID	ID
3-chloropropene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropene	ID	ID	ID	ID	ID	ID	ID	ID
ANILINES								
Aniline	8	250 ^A	1100 ^A	4800 ^A	ID	ID	ID	ID
2,4-dichloroaniline	0.6	7	20	60 ^C	ID	ID	ID	ID
2,5-dichloroaniline	ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichloroaniline	1.3	3	6 ^C	13 ^C	85	150	190	260
3,5-dichloroaniline	ID	ID	ID	ID	ID	ID	ID	ID
Benzidine	ID	ID	ID	ID	ID	ID	ID	ID
Dichlorobenzidine	ID	ID	ID	ID	ID	ID	ID	ID
AROMATIC HYDROCARBONS								
Benzene	600	950	1300	2000	500 ^C	700 ^C	900 ^C	1300 ^C
Toluene	ID	ID	ID	ID	ID	ID	ID	ID
Ethylbenzene	ID	ID	ID	ID	ID	ID	ID	ID
o-xylene	200	350	470	640	ID	ID	ID	ID
m-xylene	ID	ID	ID	ID	ID	ID	ID	ID
p-xylene	140	200	250	340	ID	ID	ID	ID
m+p-xylene	ID	ID	ID	ID	ID	ID	ID	ID
Cumene	ID	ID	ID	ID	ID	ID	ID	ID
Polycyclic Aromatic Hydrocarbons								
Naphthalene	2.5	16	37	85	50 ^C	70 ^C	90 ^C	120 ^C
Anthracene B	ID	ID	ID	ID	ID	ID	ID	ID
Phenanthrene B	ID	ID	ID	ID	ID	ID	ID	ID
Fluoranthene B	ID	ID	ID	ID	ID	ID	ID	ID
Benzo(a)pyrene B	ID	ID	ID	ID	ID	ID	ID	ID
Nitrobenzenes								
Nitrobenzene	230	550	820	1300	ID	ID	ID	ID
1,2-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloro-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloro-5-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,4-dichloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichloro-2-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID

3.4.2 How guidelines are developed for toxicants

Chemical	Trigger values for freshwater ($\mu\text{g/L}^{-1}$)				Trigger values for marine water ($\mu\text{g/L}^{-1}$)			
	Level of protection (% species)				Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
1,2,4,5-tetrachloro-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,5-dichloro-2,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trichloro-2,4-dinitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1-fluoro-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
Nitrotoluenes								
2-nitrotoluene	ID	ID	ID	ID	ID	ID	ID	ID
3-nitrotoluene	ID	ID	ID	ID	ID	ID	ID	ID
4-nitrotoluene	ID	ID	ID	ID	ID	ID	ID	ID
2,3-dinitrotoluene	ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrotoluene	16	65 ^C	130 ^C	250 ^C	ID	ID	ID	ID
2,4,6-trinitrotoluene	100	140	160	210	ID	ID	ID	ID
1,2-dimethyl-3-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dimethyl-4-nitrobenzene	ID	ID	ID	ID	ID	ID	ID	ID
4-chloro-3-nitrotoluene	ID	ID	ID	ID	ID	ID	ID	ID
Chlorobenzenes and Chloronaphthalenes								
Monochlorobenzene	ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichlorobenzene	120	160	200	270	ID	ID	ID	ID
1,3-dichlorobenzene	160	260	350	520 ^C	ID	ID	ID	ID
1,4-dichlorobenzene	40	60	75	100	ID	ID	ID	ID
1,2,3-trichlorobenzene	B 3	10	16	30 ^C	ID	ID	ID	ID
1,2,4-trichlorobenzene	B 85	170 ^C	220 ^C	300 ^C	20	80	140	240
1,3,5-trichlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,4-tetrachlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,5-tetrachlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
1,2,4,5-tetrachlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobenzene	B ID	ID	ID	ID	ID	ID	ID	ID
1-chloronaphthalene	ID	ID	ID	ID	ID	ID	ID	ID
Polychlorinated Biphenyls (PCBs) & Dioxins								
Capacitor 21	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1016	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1221	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1232	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1242	B 0.3	0.6	1.0	1.7	ID	ID	ID	ID
Aroclor 1248	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1254	B 0.01	0.03	0.07	0.2	ID	ID	ID	ID
Aroclor 1260	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1262	B ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1268	B ID	ID	ID	ID	ID	ID	ID	ID
2,3,4'-trichlorobiphenyl	B ID	ID	ID	ID	ID	ID	ID	ID
4,4'-dichlorobiphenyl	B ID	ID	ID	ID	ID	ID	ID	ID
2,2',4,5,5'-pentachloro-1,1'-biphenyl	B ID	ID	ID	ID	ID	ID	ID	ID
2,4,6,2',4',6'-hexachlorobiphenyl	B ID	ID	ID	ID	ID	ID	ID	ID
Total PCBs	B ID	ID	ID	ID	ID	ID	ID	ID
2,3,7,8-TCDD	B ID	ID	ID	ID	ID	ID	ID	ID
PHENOLS and XYLENOLS								
Phenol	85	320	600	1200 ^C	270	400	520	720
2,4-dimethylphenol	ID	ID	ID	ID	ID	ID	ID	ID
Nonylphenol	ID	ID	ID	ID	ID	ID	ID	ID
2-chlorophenol	T 340 ^C	490 ^C	630 ^C	870 ^C	ID	ID	ID	ID
3-chlorophenol	T ID	ID	ID	ID	ID	ID	ID	ID
4-chlorophenol	T 160	220	280 ^C	360 ^C	ID	ID	ID	ID
2,3-dichlorophenol	T ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichlorophenol	T 120	160 ^C	200 ^C	270 ^C	ID	ID	ID	ID

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Chemical		Trigger values for freshwater ($\mu\text{g/L}^{-1}$)				Trigger values for marine water ($\mu\text{g/L}^{-1}$)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
2,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,6-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,5-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,6-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,4,5-trichlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,4,6-trichlorophenol	T,B	3	20	40	95	ID	ID	ID	ID
2,3,4,5-tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4,6-tetrachlorophenol	T,B	10	20	25	30	ID	ID	ID	ID
2,3,5,6-tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorophenol	T,B	3.6	10	17	27 ^A	11	22	33	55 ^A
Nitrophenols									
2-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
3-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
4-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrophenol		13	45	80	140	ID	ID	ID	ID
2,4,6-trinitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
ORGANIC SULFUR COMPOUNDS									
Carbon disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
n-propyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Propyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Tert-butyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Phenyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(dimethylthiocarbamyl)sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(diethylthiocarbamyl)disulfide		ID	ID	ID	ID	ID	ID	ID	ID
2-methoxy-4H-1,3,2-benzodioxaphosphorin-2-sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Xanthates									
Potassium amyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium hexyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isobutyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium sec-butyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
PHthalATES									
Dimethylphthalate		3000	3700	4300	5100	ID	ID	ID	ID
Diethylphthalate		900	1000	1100	1300	ID	ID	ID	ID
Dibutylphthalate	B	9.9	26	40.2	64.6	ID	ID	ID	ID
Di(2-ethylhexyl)phthalate	B	ID	ID	ID	ID	ID	ID	ID	ID
MISCELLANEOUS INDUSTRIAL CHEMICALS									
Acetonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Acrylonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Poly(acrylonitrile-co-butadiene-co-styrene)		200	530	800 ^C	1200 ^C	200	250	280	340
Dimethylformamide		ID	ID	ID	ID	ID	ID	ID	ID
1,2-diphenylhydrazine		ID	ID	ID	ID	ID	ID	ID	ID
Diphenylnitrosamine		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobutadiene		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorocyclopentadiene		ID	ID	ID	ID	ID	ID	ID	ID

3.4.2 How guidelines are developed for toxicants

Chemical	Trigger values for freshwater (µg L ⁻¹)				Trigger values for marine water (µg L ⁻¹)				
	Level of protection (% species)				Level of protection (% species)				
	99%	95%	90%	80%	99%	95%	90%	80%	
Isophorone	ID	ID	ID	ID	ID	ID	ID	ID	
ORGANOCHLORINE PESTICIDES									
Aldrin	B	ID	ID	ID	ID	ID	ID	ID	
Chlordane	B	0.03	0.08	0.14	0.27 ^C	ID	ID	ID	
DDE	B	ID	ID	ID	ID	ID	ID	ID	
DDT	B	0.006	0.01	0.02	0.04	ID	ID	ID	
Dicofol	B	ID	ID	ID	ID	ID	ID	ID	
Dieldrin	B	ID	ID	ID	ID	ID	ID	ID	
Endosulfan	B	0.03	0.2 ^A	0.6 ^A	1.8 ^A	0.005	0.01	0.02	0.05 ^A
Endosulfan alpha	B	ID	ID	ID	ID	ID	ID	ID	
Endosulfan beta	B	ID	ID	ID	ID	ID	ID	ID	
Endrin	B	0.01	0.02	0.04 ^C	0.06 ^A	0.004	0.008	0.01	0.02
Heptachlor	B	0.01	0.09	0.25	0.7 ^A	ID	ID	ID	ID
Lindane		0.07	0.2	0.4	1.0 ^A	ID	ID	ID	ID
Methoxychlor	B	ID	ID	ID	ID	ID	ID	ID	ID
Mirex	B	ID	ID	ID	ID	ID	ID	ID	ID
Toxaphene	B	0.1	0.2	0.3	0.5	ID	ID	ID	ID
ORGANOPHOSPHORUS PESTICIDES									
Azinphos methyl		0.01	0.02	0.05	0.11 ^A	ID	ID	ID	ID
Chlorpyrifos	B	0.00004	0.01	0.11 ^A	1.2 ^A	0.0005	0.009	0.04 ^A	0.3 ^A
Demeton		ID	ID	ID	ID	ID	ID	ID	ID
Demeton-S-methyl		ID	ID	ID	ID	ID	ID	ID	ID
Diazinon		0.00003	0.01	0.2 ^A	2 ^A	ID	ID	ID	ID
Dimethoate		0.1	0.15	0.2	0.3	ID	ID	ID	ID
Fenitrothion		0.1	0.2	0.3	0.4	ID	ID	ID	ID
Malathion		0.002	0.05	0.2	1.1 ^A	ID	ID	ID	ID
Parathion		0.0007	0.004 ^C	0.01 ^C	0.04 ^A	ID	ID	ID	ID
Profenofos	B	ID	ID	ID	ID	ID	ID	ID	ID
Temephos	B	ID	ID	ID	ID	0.0004	0.05	0.4	3.6 ^A
CARBAMATE & OTHER PESTICIDES									
Carbofuran		0.06	1.2 ^A	4 ^A	15 ^A	ID	ID	ID	ID
Methomyl		0.5	3.5	9.5	23	ID	ID	ID	ID
S-methoprene		ID	ID	ID	ID	ID	ID	ID	ID
PYRETHROIDS									
Deltamethrin		ID	ID	ID	ID	ID	ID	ID	ID
Esfenvalerate		ID	0.001 [*]	ID	ID	ID	ID	ID	ID
HERBICIDES & FUNGICIDES									
Bypyridilium herbicides									
Diquat		0.01	1.4	10	80 ^A	ID	ID	ID	ID
Paraquat		ID	ID	ID	ID	ID	ID	ID	ID
Phenoxyacetic acid herbicides									
MCPA		ID	ID	ID	ID	ID	ID	ID	ID
2,4-D		140	280	450	830	ID	ID	ID	ID
2,4,5-T		3	36	100	290 ^A	ID	ID	ID	ID
Sulfonylurea herbicides									
Bensulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Metsulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Thiocarbamate herbicides									
Molinate		0.1	3.4	14	57	ID	ID	ID	ID
Thiobencarb		1	2.8	4.6	8 ^C	ID	ID	ID	ID
Thiram		0.01	0.2	0.8 ^C	3 ^A	ID	ID	ID	ID
Triazine herbicides									
Amitrole		ID	ID	ID	ID	ID	ID	ID	ID
Atrazine		0.7	13	45 ^C	150 ^C	ID	ID	ID	ID

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Chemical	Trigger values for freshwater ($\mu\text{g L}^{-1}$)				Trigger values for marine water ($\mu\text{g L}^{-1}$)			
	Level of protection (% species)				Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
Hexazinone	ID	ID	ID	ID	ID	ID	ID	ID
Simazine	0.2	3.2	11	35	ID	ID	ID	ID
Urea herbicides								
Diuron	ID	ID	ID	ID	ID	ID	ID	ID
Tebuthiuron	0.02	2.2	20	160 ^C	ID	ID	ID	ID
Miscellaneous herbicides								
Acrolein	ID	ID	ID	ID	ID	ID	ID	ID
Bromacil	ID	ID	ID	ID	ID	ID	ID	ID
Glyphosate	370	1200	2000	3600 ^A	ID	ID	ID	ID
Imazethapyr	ID	ID	ID	ID	ID	ID	ID	ID
loxylin	ID	ID	ID	ID	ID	ID	ID	ID
Metolachlor	ID	ID	ID	ID	ID	ID	ID	ID
Sethoxydim	ID	ID	ID	ID	ID	ID	ID	ID
Trifluralin B	2.6	4.4	6	9 ^A	ID	ID	ID	ID
GENERIC GROUPS OF CHEMICALS								
Surfactants								
Linear alkylbenzene sulfonates (LAS)	65	280	520 ^C	1000 ^C	ID	ID	ID	ID
Alcohol ethoxylated sulfate (AES)	340	650	850 ^C	1100 ^C	ID	ID	ID	ID
Alcohol ethoxylated surfactants (AE)	50	140	220	360 ^C	ID	ID	ID	ID
Oils & Petroleum Hydrocarbons								
Oil Spill Dispersants								
BP 1100X	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 7664	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 8667		ID	ID	ID	ID	ID	ID	ID
Corexit 9527	ID	ID	ID	ID	230	1100	2200	4400 ^A
Corexit 9550	ID	ID	ID	ID	ID	ID	ID	ID

Notes: Where the final water quality guideline to be applied to a site is below current analytical practical quantitation limits, see Section 3.4.3.3 for guidance.

Most trigger values listed here for metals and metalloids are *High reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3 for reference to Volume 2). The exceptions are *Moderate reliability* for freshwater aluminium (pH >6.5), manganese and marine chromium (III).

Most trigger values listed here for non-metallic inorganics and organic chemicals are *Moderate reliability* figures, derived from acute LC₅₀ data (see 3.4.2.3 for reference to Volume 2). The exceptions are *High reliability* for freshwater ammonia, 3,4-DCA, endosulfan, chlorpyrifos, esfenvalerate, tebutiuron, three surfactants and marine for 1,1,2-TCE and chlorpyrifos.

* = *High reliability* figure for esfenvalerate derived from mesocosm NOEC data (no alternative protection levels available).

A = Figure may not protect key test species from acute toxicity (and chronic) — check Section 8.3.7 for spread of data and its significance. 'A' indicates that trigger value > acute toxicity figure; note that trigger value should be <1/3 of acute figure (Section 8.3.4.4).

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (see Sections 8.3.3.4 and 8.3.5.7).

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) — check Section 8.3.7 for spread of data and its significance. Where grey shading and 'C' coincide, refer to text in Section 8.3.7.

D = Ammonia as TOTAL ammonia as [NH₃-N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2.

E = Chlorine as total chlorine, as [Cl]; see Section 8.3.7.2.

F = Cyanide as un-ionised HCN, measured as [CN]; see Section 8.3.7.2.

G = Sulfide as un-ionised H₂S, measured as [S]; see Section 8.3.7.2.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L CaCO₃. These should be adjusted to the site-specific hardness (see Section 3.4.3).

J = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is the issue of concern.

ID = Insufficient data to derive a reliable trigger value. Users advised to check if a low reliability value or an ECL is given in Section 8.3.7.

T = Tainting or flavour impairment of fish flesh may possibly occur at concentrations below the trigger value. See Sections 4.4.5.3/3 and 8.3.7.

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APPENDIX G3

Long Term Trigger Values for Irrigation Water

CMJA

4.2.6 Heavy metals and metalloids

Table 4.2.9 Effect of sodium expressed as sodium adsorption ratio (SAR) on crop yield and quality under non-saline conditions^a

Tolerance to SAR and range at which affected	Crop	Growth response under field conditions
Extremely sensitive SAR = 2–8	Avocado Deciduous fruits Nuts Citrus	Leaf tip burn, leaf scorch
Sensitive SAR = 8–18	Beans	Stunted growth
Medium SAR = 18–46	Clover Oats Tall fescue Rice Dallis grass	Stunted growth, possible sodium toxicity, possible calcium or magnesium deficiency
High SAR = 46–102	Wheat Cotton Lucerne Barley Beets Rhodes grass	Stunted growth

a After Pearson (1960); SAR = Sodium Adsorption Ratio (see Section 4.2.4.1)

4.2.6 Heavy metals and metalloids

Long-term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in table 4.2.10. Concentrations in irrigation water should be less than the recommended trigger values.

Table 4.2.10 Agricultural irrigation water long-term trigger value (LTV), short-term trigger value (STV) and soil cumulative contaminant loading limit (CCL) triggers for heavy metals and metalloids^a

Element	Suggested soil CCL ^b (kg/ha)	LTV in irrigation water (long-term use — up to 100 yrs) (mg/L)	STV in irrigation water (short-term use — up to 20 yrs) (mg/L)
Aluminium	ND	5	20
Arsenic	20	0.1	2.0
Beryllium	ND	0.1	0.5
Boron	ND	0.5	Refer to table 9.2.18 (Volume 3)
Cadmium	2	0.01	
Chromium	ND	0.1	1
Cobalt	ND	0.05	0.1
Copper	140	0.2	5
Fluoride	ND	1	2
Iron	ND	0.2	10
Lead	260	2	5
Lithium	ND	2.5	2.5
		(0.075 Citrus crops)	(0.075 Citrus crops)
Manganese	ND	0.2	10
Mercury	2	0.002	0.002
Molybdenum	ND	0.01	0.05
Nickel	85	0.2	2
Selenium	10	0.02	0.05
Uranium	ND	0.01	0.1
Vanadium	ND	0.1	0.5
Zinc	300	2	5

a Trigger values should only be used in conjunction with information on each individual element and the potential for off-site transport of contaminants (Volume 3, Section 9.2.5)

b ND = Not determined; insufficient background data to calculate CCL